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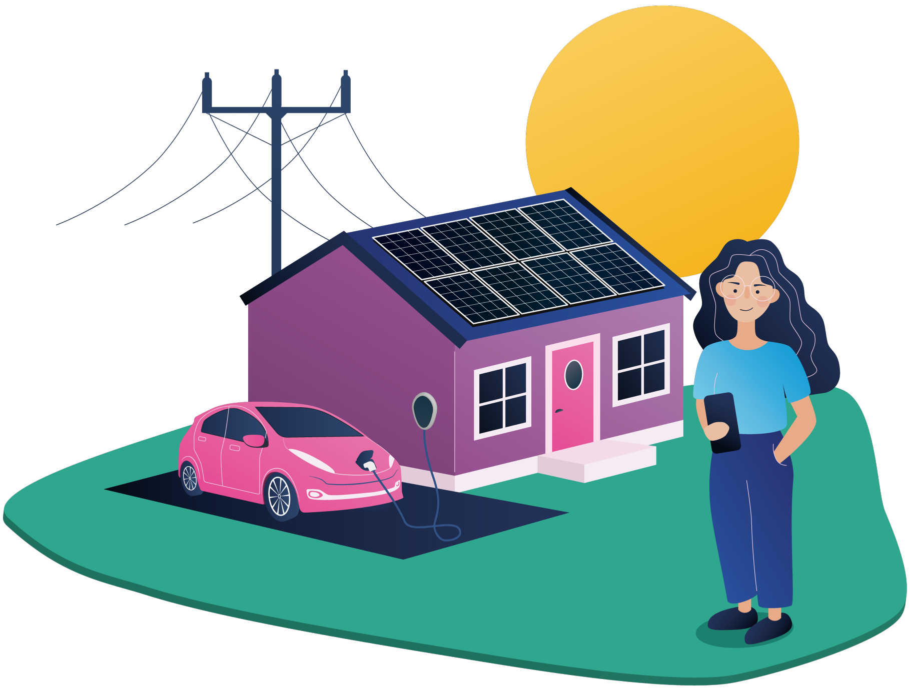

Energy flow in a household

A study on how to visualise and motivate energy saving behaviour

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Master's thesis in Industrial Design Engineering

DEPARTMENT OF INDUSTRIAL AND MATERIAL SCIENCE

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Master of Science Thesis (IMSX30)

Energy flow in a household - A study on how to visualise and motivate energy saving behaviour

In collaboration with Eliq

Cover illustration: A user interacting with a mobile application infront of their house with solar panels and an electric vehicle.

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Abstract

Almost a third of the electricity in Sweden is used by households, and at approximately the same time of the day. This puts a strain on the electric grid and increases the risk of electricity shortage, mostly caused by lack of capacity. As the number of electric vehicles is increasing, the issue becomes even more pressing. There is therefore a need to enhance awareness among electricity consumers and their consumption behaviour. Furthermore, the installations of domestic solar power facilities has increased rapidly and is believed to continue to increase exponentially in the next few years. There is therefore also a need to support small-scale solar power producers and to integrate their production with their consumption.

This master thesis has aimed to investigate how the flow of electricity throughout the household can be displayed, including both consumption, production via solar panels and charging of the electric vehicles. This thesis has also investigated what factors affect users' energy consuming behaviour and how the consumption could be communicated so that they understand the environmental impact.

The project was initiated with a market analysis to find similar solutions, followed by an explorative phase simultaneously as an ideation phase. During the exploration phase interviews with users and experts, questionnaires and literature studies were conducted. During the ideation phase, ideas to discuss and evaluate with users during the interviews were developed. These phases resulted in guidelines and insights that were used for the concept development. The concepts were prototyped and evaluated theoretically and with users with positive results. Lastly, a final design proposal was developed.

The result is a design proposal integrating the household consumption, production and charge of the electric vehicles in the same mobile application. The application shows the flow of electricity in the household and information on production and consumption, and motivates and makes the user more aware of their consumption. Additionally, factors affecting the electricity consuming behaviour have been investigated and insights and guidelines for further development have been established.

Keywords: *electricity, energy flow, mobile application, solar panels, electric vehicle, behaviour change, user studies*

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Terminology

PV = Photovoltaic.

Solar panels can also be called photovoltaic panels or PV panels.

EV = Electric vehicle.

A vehicle powered by electric power instead of carbon-based fuel.

EHV = Electric hybrid vehicle.

A vehicle powered by a combination of carbon-based fuel and electric power.

DSO = Distribution System Operator.

Own the electric grid within a certain grid area and are responsible for transporting electricity to end customers.

TSO = Transmission System Operator.

Electric grid running across the entire country transporting electricity from power plants to the regional grid.

Prosumer = Producer and consumer.

A household which at times produces surplus energy that can be fed into the distribution network and at other times consume energy from the grid. In this thesis, *prosumer* will be used to describe households with domestic solar power facilities.

Energy = Electric energy, electricity.

At times when *energy* is being used in this thesis, it is electric energy or electricity that is intended.

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1

INTRODUCTION

In this chapter, an introduction to the thesis project is presented. This includes background information and information about the collaboration company, the project scope and a walkthrough of the project process.

1.1 Background

Sweden produces approximately 165 600 GWh of electricity each year. Out of this, 28% is consumed by households (Statistiska Centralbyrån [SCB], 2021a). An average household living in a detached house in Sweden consumes approximately 20 000 kWh per year, which results in a cost of roughly 31 000 SEK (Konsumenternas Energimarknadsbyrå, 2020). Furthermore, this corresponds to 1,8 tonnes of carbon dioxide emissions, based on the Nordic energy mix, calculated by utslappsratt.se. Lowering the energy consumption by households would decrease both their utility costs and the negative impacts on the environment. As households stand for a substantial part of the national energy consumption there is a possibility for significant improvement.

In 2019 only 0,4% of the total energy production was derived from solar power, however, there is a continuous increase in the number of solar power installations (SCB, 2021a). During 2019, the installed solar power increased with 70% of which the majority derives from facilities below 20 kW, meaning regular households (Energimyndigheten, 2020). The excess power can be stored in a battery for a shorter period of time, or sold to electricity retailers (Solcellskollen, n.d.). To support the increasing number of prosumers, there is a need to expand the visualisation of energy flow in the household to not only include consumption, but also production.

The market for electric vehicles [EV] and electro hybrid vehicles [EHV] is growing fast in Sweden. In 2019, 11,3% of the newly registered cars in Sweden were chargeable, in 2020 the number had increased to 32,2% (Bil Sweden, 2021). The increasing number of EV's and EHV's increases the strain on the electric grid, as the power peak demand is getting larger. This brings concerns on capacity shortage (Wang, Nian, Li, Yuan, 2021). To meet the increased number of EVs and EHV's, it is crucial that the users understand the critical issues that will emerge if everyone charges their car at the same time. There is therefore a need to include charging of EV's and EVH's in the household electricity flow.

1.1.1 Eliq

This project will be conducted in collaboration with Eliq. Eliq provides software and a white-label app to electricity retailers, which they in turn offer their customers. On the electricity market, the churn is high as regular customers spend only a few minutes interacting with their electricity retailer every year. A high churn means a low motivation for customers to remain with their electricity provider as they build no relationship with each other. As a way to decrease the churn, electricity retailers wish to offer personalised solutions to increase the customer engagement. Eliq's solution compares information from electricity retailers with factors like weather and smart home data from third party applications to create a greater value and increase the customer engagement. Eliq works with companies such as Vattenfall, Bixia and Mölndal Energi in Sweden, but also has customers abroad. This thesis project will focus on the demo version of the mobile application, which is used to attract new customers.

1.2 Project scope

This section defines the project scope by first describing the desired outcome through the aim, followed by the research questions and the deliverables of the project. Finally, the demarcations describe the boundaries.

1.2.1 Aim

The aim of this master thesis is to investigate how the flow of electricity throughout the entire household could be displayed to the user, including consumption, production via solar panels and charging of electric vehicles. Furthermore, the thesis aims to investigate what factors affect users' energy consuming behaviour and how the consumption could be communicated so that the users understand their environmental impact.

1.2.2 Research questions

To guide the project work, research questions have been defined. The questions that this thesis aim to answer are as follows:

- How can the energy flow in a household be visualised?
- How can electric vehicle charging be incorporated?
- How can domestic solar power production be incorporated?
- How can users be motivated to reduce their energy consumption?
- What factors affect electricity consuming behaviour?

1.2.3 Deliverables

The intended outcome and deliverables of the project are as follows:

- Mapping the needs of prosumers and consumers today and in the near future.
- A set of guidelines to guide the design work and further development.
- A visual design concept meeting the needs and guidelines.

1.2.4 Demarcations

To narrow down the scope of this project, and to avoid it becoming too broad, some demarcations were applied. These are as follows:

- The research and design proposal will target the Swedish market.
- The study will focus on household's electricity consumption.
- The research and design concept will focus on electricity consumption, and does not take costs for grid connection into consideration.
- The design concept should be implementable in the near future, within a timeframe of 5 years.
- The project will have to adapt to the current restrictions provided by the The Public Health Agency of Sweden, due to the prevailing Covid-19 pandemic.

Figure 1.1. The project process.

1.3 Project process

An overview of the project process is shown in figure 1.1. The project was initiated with defining its scope, thereafter a market analysis was conducted to gain an understanding of the current market trends and what the solution looks like today. The market analysis was initiated with a benchmarking investigating similar solutions, but also solutions more specifically targeting solar panels or EV owners. This was followed by a usability analysis of Eliq's current design. The benchmarking provided an insight into what competitors' solutions look like, as well as a list of common attributes for the solutions. The usability analysis was useful as it provided an insight into what should be retained and what might benefit from a redesign, as well as an understanding of the design language of the current solution.

Following the market analysis, the exploration phase and the ideation phase were conducted in parallel. The exploration phase aimed to gain an understanding of household electricity consumption, what factors can affect electricity consuming behaviour as well as users' needs on monitoring electricity consumption and production from solar panels. The main deliverable of the phase was a basis for creating design guidelines. The phase was initiated with a literature study which continued throughout the phase. This provided insights on previous studies on the topic. Furthermore, a questionnaire survey was conducted in order to reach a broad target group to receive statistics and a large quantity of inputs. Interviews were held with both users and experts on different areas. Prior to the user interviews, an initial ideation was conducted, with the aim to use the result as mediating tools during the interviews. This furthermore allowed for an early iteration of the ideas. The participants of the user interviews were sampled based on accommodation, if they used an app or not for electricity monitoring and whether or not they owned an EV or had solar panels. At the end of the interviews the participants were shown the result of the ideation; a number of ways to illustrate a number of attributes that could be included in the app. They were asked to speak their opinion, discuss and come up with new ideas in collaboration with the interviewer. The results from the exploration phase were analysed with help of an Affinity diagram, and the qualitative results were summarised in four personas. The ideation phase furthermore consisted of a symbol survey with alternative ways to design symbols to be used in the app. The symbol survey also consisted of a colour-evaluation to collect thoughts on how people interpret colours. Furthermore, the result from the market analysis, the exploration phase and the ideation phase served as a basis for guidelines and insights guiding the following phases of the project.

The concept development phase aimed to use the findings from the previous phases, including the insights and design guidelines to ideate and to create concepts on what a future solution could look like. The aim of this phase was to create concepts to be evaluated during the next phase. The concept development phase was initiated with an ideation process where the results from the feedback on the ideas from the ideation phase were iterated and new ideas were created. The concepts were thereafter developed and a prototype was created.

During the evaluation phase the concept and ideas developed in the previous phase were evaluated. The evaluation was conducted both with users and theoretically with help of the guidelines and the personas. The aim of this phase was to receive feedback and suggestions for improvement for the final solution, as well as thoroughly evaluate whether each guideline had been met or not. Important notes and feedback were brought forward to the development of the final solution.

Based on the evaluation, the concepts from the concept development phase were altered to better fit user needs and the digital prototype was improved to create the final design proposal.

2

THEORY

This chapter presents the theory used in this thesis project. The theory covers the topics of the Swedish electricity market as well as design theories that have been implemented during the project. In the following sections electricity in Sweden and some related issues, solar power and design theories will be presented.

2.1 Electricity in Sweden

During 2019, Sweden produced 164,6 TWh of electricity. How the electricity was produced is shown in figure 2.1. Sweden has focused on energy efficiency and switching from fossil fuels to renewables, and aims for 100 % renewables by 2040. However, the Swedish electricity generation is almost decarbonized already due to high generation from hydro, nuclear and wind power (International Energy Agency [IEA], 2021). As can be seen in ElectricityMap (2021) the greenhouse gas emissions caused by electricity usage in Sweden are approximately 46 gCO_2eq/kWh, but varies slightly from day to day. This can be compared with the global average carbon intensity of 475 gCO_2/kWh (IEA, 2019).

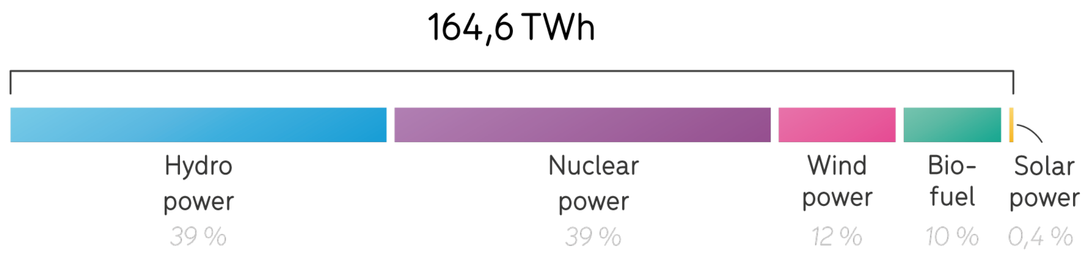


Figure 2.1. Distribution of energy sources in Sweden (SCB, 2021a).

Approximately 131,8 TWh of electricity was consumed in Sweden in 2019, and the curve for total consumption has been rather flat the last 30 years. However, as the population has increased, consumption per capita has decreased, from 15,8 MWh to 12,8 MWh per year, corresponding to an almost 20% decrease (IEA, 2021). Out of this, 28% is consumed by households to heat up buildings and for use of domestic appliances (SCB, 2021a).

2.1.1 Power exchange between countries

Of the electricity produced in Sweden, 35,2 TWh, equal to 21 %, were exported to other countries, mostly to Finland. Exporting renewable electricity to the European market contributes to higher availability of clean energy in Europe. Sweden also imported 9 TWh during the year, mostly from Norway (Energimyndigheten, 2020). Sweden and 15 other European countries are continuously exchanging power on the power market called Nord Pool. The power market is thus deregulated, meaning that no state is running the power market but free competition prevails. This enables a more efficient market and an increased security of demand as many different energy sources enter the grid (Nord Pool, n.d.a).

2.1.2 Stakeholders

There are several stakeholders operating in the electricity market. The electricity producers supply the market with power from their power plants. A producer can be both large energy corporations and small-scale domestic solar power facilities (Energimarknadsinspektionen [EI], 2015). There are hundreds of electricity producers in Sweden, of which the four largest collectively produce over 70 % of the total electricity that is being produced (Konsumenternas Energimarknadsbyrå, 2020e). The electricity producers sell electricity on the European energy market Nord Pool, where the electricity retailers purchase it for selling to their customers (EI, 2015). For end customers there is no collective energy market between the Nordic countries, which means that customers can only buy electricity from electricity retailers operating in

Sweden. The end customer can choose freely which electricity retailer to sign a deal with. Customers are however not able to freely choose a Distribution System Operator [DSO], as they have a geographic monopoly and cover a certain grid area (Konsumenternas Energimarknadsbyrå, 2020d). DSO's own the electric grid and are responsible for transporting electricity from where it has been produced to the end customers. There are furthermore three levels of electric grid: Transmission System Operator [TSO], regional grid and local grid (shown in figure 2.2). The TSO runs across the entire country, transporting electricity from the producers to the regional grid. In turn, the local grid transports the electricity from the regional grid to the end customers within a certain area (EI, 2015).

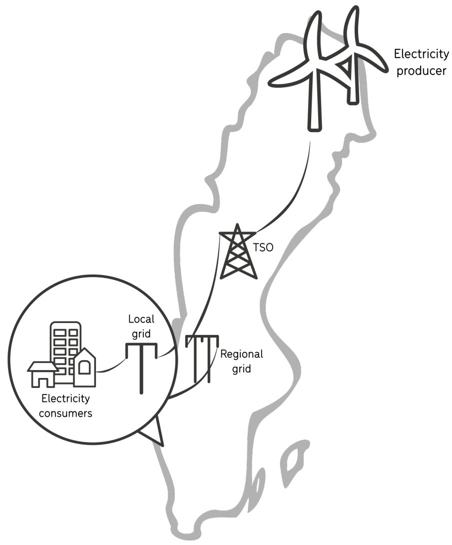


Figure 2.2. The levels of the electric grid in Sweden.

2.1.3 Price of electricity

The price of electricity is decided based on supply and demand, with factors like weather and current efficiency of power plants influencing the prices (Nord Pool, n.d.a). It is important to reach a balance between supply and demand in the power market, mostly due to the inability to store electricity in large quantities and due to high costs related to a failure of supply (Nord Pool, n.d.b).

The prices are decided one day ahead and are auction-based. Power producers and consumers are placing bids and offers and a balancing hourly price is determined for the next day. The orders placed by the customers specify the amount of MW per time unit and to what price they are willing to sell or buy (EUR/MWh) for each hour of the next day (Nord Pool, n.d.b). In addition to day-ahead trading, there is also an intraday trading market integrating 14 countries in Europe, which enables trading of electricity closer to the delivery and thereby taking unexpected events into account. This trading is taking place around the clock up until one hour before delivery. The intraday trading has increased in interest as larger quantities of intermittent energy sources are being used in production (Nord Pool, n.d.c).

The main difference between price setting in the power market compared to other commodity markets is the significantly higher requirements as electricity must be delivered to the consumer at the exact moment of use (Nord Pool, n.d.b).

2.1.4 Tariffs

The most common tariff today is a charge based on the size of the fuse in a household, which regulates how much electricity that can enter the house. This is however independent of how much is actually being used. Power tariffs are increasingly being introduced and are a way to motivate consumers to more efficiently utilise the electric grid. The hour the consumer uses the most power during one month will affect the tariff charge for that month, meaning each household is able to affect the monthly charge by shifting the consumption (EI, 2015). This means that if several appliances are at use simultaneously the effect peak will be high, thus leading to a higher charge. If the use of the appliances are instead spread out during a day, the effect peak will be lower and thus leading to a lower charge. In figure 2.3a the laundry is being done simultaneously as the EV is charged, which leads to a high peak during one hour. In figure 2.3b however, the laundry is done the next hour, thus avoiding the high peak. The exact way this is implemented varies. One example is Karlstads El- och Stadsnät (2021), who explains the way they have implemented it as a charge depending on the power peak of the month, and an additional charge November to March between 06-18 Monday to Friday, as the strain is usually higher at those times.

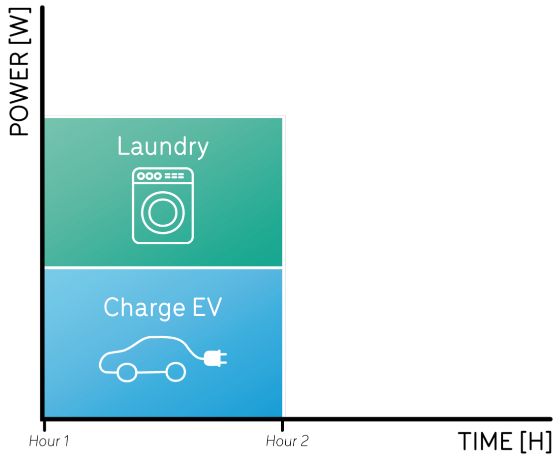


Figure 2.3a. Simultaneous use of appliances.

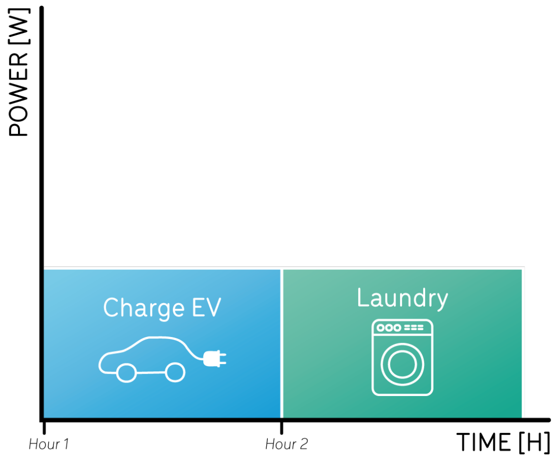


Figure 2.3b. Use of appliances over 2 h.

2.2 Shortage issues

If the production of electricity cannot supply the demand, a shortage of available electricity occurs. A shortage of electricity can have two causes; lack of capacity in the electric cables to transport the electricity from power plants to the place of demand, and lack of power to meet peak demand (Holmström, 2021). Both of these issues will be explained in the sections below.

2.2.1 Capacity shortage

Lack of availability in the electric cables to transport electricity leads to lack of capacity as bottlenecks are formed. This issue mostly emerges locally when new industries want to establish and often close to larger cities. The issue is most prominent during cold, cloudy winter days when the demand for electricity is at its peak (E.ON, 2020a). As described by E.ON (2020b), the development of the electric grid in Sweden was initiated in the 1920s and expanded as the country developed between the 1960s-1980s. However, the use of electricity has grown immensely since then with the introduction of the internet and increased demand for electric transportation. Huge amount of electricity is produced in northern parts of Sweden, which also has a low population. In the south of Sweden the population is much larger, but there is usually a lack of produced electricity (Konsumenternas Energimarknadsbyrå, 2020e). Lack of capacity can lead to simultaneous overproduction and lack of electricity in different parts of the country, as bottlenecks emerge when transporting the produced electricity to where it is needed as well as lack of possibilities to store energy (Holmström, 2021). Other consequences of the lack of capacity are that businesses are prohibited to expand with new industries, new neighbourhoods cannot be built as they cannot be connected to the already strained electric network and the increased demand for electric transportation to outphase the use of fossil fuels cannot be met (E.ON, 2020a).

2.2.2 Power shortage

Lack of power mainly occurs a few hours during cold winter days, as the demand for energy exceeds production. In such a scenario the country is forced to rely on import of electricity from other European countries, which might not be as clean as electricity produced in Sweden (EI, 2018). Moreover, there are no guarantees that other countries are able to export their electricity, which in such a case could lead to power outages in parts of the country (Holmström, 2021). Since wind power is an intermittent power source its production varies with weather, and most days it is supported by non-intermittent sources like hydro and nuclear power. However, if the normal production is disrupted Sweden has an oil power reserve plant in Karlshamn. (EI, 2018) This was recently a prevailing issue in Sweden, as the Karlshamn oil power plant was forced to start production in the beginning of February 2021, as a consequence of cold and windless weather for several days in all of Scandinavia. This was reported by several newspapers, for example Ny Teknik (2021).

2.3 Solar power

The worldwide installation rate of renewable energy is accelerating and is believed to reach a new record during 2021. Furthermore, it is believed that the installed capacity of wind and solar power will surpass that of natural gas in 2023 and that of coal in 2024 (IEA, 2020). The production of electricity by solar power is a relatively new technology that has entered the market, but since 2010 it has grown by more than 7000% in Sweden, from 9 GWh to 663 GWh 2019 (IEA, 2021). However, it still represents only 0,4% of the total electricity production in Sweden (SCB, 2021a).

The most common method to transform solar energy into electricity is by using Photovoltaic [PV] cells. They are commonly manufactured from silicon and use the photoelectric effect to create an electric current. PV cells consist of two semi-conductive layers creating a P-N junction, sandwiched between conductive layers. The N-layer has an abundance of electrons and when sunlight falls on it they wander to the P-layer, creating a voltage difference, and thus creating an electric current transforming the potential energy into electricity (Smerdon & Smerdon, 2018).

The use of solar power has great potential as the solar energy reaching the surface of the Earth is 10,000 times more than what the entire population uses (TED-Ed, 2016). Furthermore, Smerdon & Smerdon (2018) argues that PV cells offer high flexibility, since thousands of panels could be mounted together to create solar farms, or just a few panels could be installed on domestic houses satisfying local demand. As explained by Richard Komp in TED-Ed (2016) solar panels also have a long life span as nothing is being worn out as energy is being transformed. Intergovernmental Panel of Climate Change [IPCC] (2014) presents life cycle assessments on emissions from energy sources. The greenhouse gas emissions from PV is believed to be 18-180 gCO_2eq/kWh, from which the majority is derived from infrastructure and supply chain emissions.

However, the efficiency of solar power is still a challenge, as commercial solar cells only reach an efficiency of 16-20%. The main issue is that materials used to manufacture PV cells only absorb a narrow range of the full spectrum of energy from the photons (Smerdon & Smerdon, 2018). Furthermore, the availability of solar power is unevenly distributed over the globe as some places are sunnier than others, as well as a variation in weather. To be able to completely rely on solar power, TED-Ed (2016) states that an efficient way to transport and store energy is required. Large areas of land are also required to produce sufficient amounts of energy. Smerdon & Smerdon (2018) argue that the most pervasive challenge is that solar power is an intermittent source of energy, meaning that its intensity and availability vary depending on weather and time of day. This becomes a problem as utility companies must be ready to meet the peak demand with conventional, non-intermittent power capacity to even out fluctuations, leading to conventional plants not being utilised during long periods of times.

2.4 Design Theory

During the development of the concepts, design theories were used. Usability was used as an evaluation criteria of the current solution, and usability and colour theory was used as a basis to formulate guidelines. The definition of usability and 10 principles of useful design are presented in the sections below, as well as important colour theory.

2.3.1 Usability

Usability is defined as *"the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"* (International Organization for Standardization [ISO], 2018). To guide in designing for usability, Patrick Jordan (1998) introduced 10 principles of useful design which describes elements in an interface which affect its usability. These principles are as follows:

1. *Consistency* - within the product, similar tasks are solved in a similar way to help users generalise actions.
2. *Compatibility* - tasks within the product are solved in a similar way as in the rest of the world to not oppose users' mental models.
3. *Consideration of user resources* - the user's mental resources during use are taken into consideration.
4. *Feedback* - the product indicates that it has registered the user's actions as well as giving meaningful information on the result of the actions.
5. *Error prevention and recovery* - the risk of use errors are minimised and quick recovery is possible.
6. *User control* - the user's experienced control over the product is maximised without exaggeration.
7. *Visual clarity* - information is easily readable without causing confusion.
8. *Prioritisation of functionality and information* - the most important functions are prioritised and easily accessible for the user.
9. *Appropriate transfer of technology* - appropriate technology developed in other circumstances are utilised in the product.
10. *Explicitness* - the product gives clear clues on how it can be used and what the user can do with it.

2.3.2 Colour theory

This section will present a number of colour theories that have been utilised in the design work. When choosing colours for an app design, it is important to avoid combining colours that make it difficult for people to perceive the content (Apple Developer, n.d.a). For example, some colourblind people can not distinguish blue from orange, or red from green, and it should therefore be avoided to use these colour combinations as the only way to distinguish between two states (Apple Developer, n.d.b). Moreover, inadequate contrast between text or icons and background results in low readability. The sufficient contrast depends on the size and weight of the text or icon; smaller texts require higher contrast. It is suggested by Apple Developer (n.d.b) to have a contrast ratio of minimum 4,5:1 for texts smaller than 17 pt, and 3:1 for larger text sizes. However, if the text is bold, a minimum contrast ratio of 3:1 is acceptable for all text sizes. The user should be able to understand which elements on the screen are interactive. Furthermore, it is important that text and icons are distinctly different from the background colour to enhance readability (UX Collective, 2018).

3

METHODOLOGY

This chapter briefly presents the theoretical framework of the methods used during the project. How the methods were implemented are thoroughly presented in the procedure-sections in chapter 4, 5, 6, 8 and 9.

3.1 Benchmarking

Benchmarking can be done both to understand the market and to help during the concept generation. Competitive benchmarking is important for successful positioning of a product. Benchmarking of related products can also give information on how existing products have solved particular problems as well as the strengths and weaknesses of the competition. Products of interest can be products in the same market, products with similar functionality or products with similar subproblems as the one in development (Ulrich, Eppinger & Yang, 2020).

3.2 Positional mapping

A positional map shows the positioning of a company or brand within a market, as explained by Wells (2020). To create a positional map, a segmentation based on a target group is first conducted. Segments could be based on for example psychographic, demographic or behavioural factors. Thereafter, attributes to target and their opposites are defined and placed on a x- and y-axis. These should be attributes important to the targeted consumers, to motivate them to pick one company over others. Finally, market opportunities are identified and the company can position themselves in relation to competitors on a map consisting of the axises.

3.3 Literature review

A literature review is a qualitative and exploratory method of secondary research, essential for academic papers but also useful for design projects. Literature reviews are used to collect and synthesise information on a given topic from previous research. Literature reviews can include a diverse range of references, including books, journals and magazine articles but also websites and blogs. However, caution should be taken so that the chosen sources not only contain relevant information but are also credible, preferably vetted or peer reviewed for credibility. It is generally not necessary to summarise everything from each source but the information should be converged and synthesised (Hanington & Martin, 2012).

3.4 Questionnaire survey

Questionnaires are efficient and can collect a large amount of data in a short period of time. It collects self-reported information including, but not limited to, people's characteristics, behaviours, feelings and attitudes. It is also suitable for reaching a large and dispersed set of people. A question can be constructed in different ways which affects what kind of response is given and how it can be analysed. For example, closed-ended questions are easier to analyse numerically while open-ended questions provide an opportunity for more in-depth answers (Hanington & Martin, 2012).

3.5 Interview

Interviews are a type of qualitative research where questions can be asked directly to users and experts in order to gain knowledge and understanding (Wikberg Nilsson, Ericson & Törlind, 2015). From users it is possible to collect information about for example experiences, opinions, and attitudes regarding products and services and from experts one can gain a deeper understanding around a certain topic.

Interviews can be used in several phases in the design process (Wikberg Nilsson et al., 2015). In the beginning of the design process interviews can be used to gain insights about how current products are used and how users think and behave etc. During later stages of the design process users can give feedback on developed concepts.

Interviews can be either structured, unstructured or semi-structured (Wikberg Nilsson et al., 2015). In a structured interview there are pre-determined questions asked in a structured way. Unstructured interviews are more like discussions where the interviewee can talk more freely about a topic of interest. In a semi-structured interview there are some prepared questions and topics to talk about, but there is also room for flexibility, probes and follow-up questions.

3.6 Affinity diagram

Affinity diagrams can be used to synthesise and interpret qualitative research data by structuring the data into groups (Hanington & Martin, 2012). Material from the research such as comments and observations from interviews is written down on notes and then clustered together based on their relationship. The analysis with the affinity diagram is conducted bottom-up, meaning that the groups are not formed beforehand but appear during the procedure as connections are discovered.

3.7 Persona

A persona is a fictional description of a user profile belonging to the targeted user group, created to keep a user-centered focus during the design process and to create and support empathy towards users and their needs (Wikberg Nilson et al., 2015). The persona is based on the studies of users and their context, including for example the result from statistics, interviews and observations. Wikberg Nilsson et al. (2015) furthermore suggest that giving the persona a name, a picture and to describe them with background information and personal details rather than numerical facts will make them more realistic and relatable. Creating a scenario and a goal for the persona in the use context will further support the understanding of the character. Hanington & Martin (2012) suggest that a maximum of 3-5 personas should be developed for a project, to keep a manageable focus and to avoid designing for the extreme users. They furthermore argue that human descriptions and distinct differences between different personas create design targets, as it otherwise could be challenging to try to design for everyone.

3.8 Ideation methods

There are many available methods to help facilitate creativity and innovation. In this section, the ideation methods used in this project are described.

3.8.1 Brainstorming

Brainstorming is a method used to generate a large quantity of ideas. The method can be performed individually or in a group. If performed in a group, it is important that all participants feel comfortable sharing their ideas so that no creativity is constrained. Also, when performing brainstorming in a group, the participants' creativity is stimulated by hearing and seeing other people's ideas. Brainstorming can be performed in a variety of ways, but is often conducted using pen and paper, and often starts with defining a question to ideate around (Wikberg Nilsson et al., 2015).

3.8.2 Braindrawing

Braindrawing is a brainstorming method, where the participants individually brainstorm ideas that they draw on paper during a fixed time, whereafter the piece of paper is passed on to another participant who can continue to draw on the ideas, or can be inspired by the previous ideas. The session starts by defining a topic to ideate around, and when the session ends the drawn ideas are discussed and potentially developed further (Wikberg Nilsson et al., 2015).

3.8.3 Morphological matrix

A morphological matrix is a method to generate solutions to part-problems or desired functions that have been identified. It is a structured way to quickly generate a large quantity of part-solutions, and can help see beyond complex problems and focus on smaller challenges. The method begins with making a list of all functions the final solution shall include, whereafter all possible solutions to each function are written down. Finally, the part-solutions for the functions are combined into concepts which are evaluated (Wikberg Nilsson et al., 2015).

4

MARKET ANALYSIS

This chapter presents the market analysis, which consisted of benchmarking to find similar solutions, a positional mapping and a usability analysis of Eliq's current solution. In the following sections the procedure and findings will be presented, as well as some conclusions that were the outcome of this phase.

4.1 Aim

The main purpose of the market analysis was to gain an insight into what the market of electricity monitoring mobile apps looks like today as well as understanding how Eliq's current solution fits the market.

4.2 Procedure

The methods used in this phase were benchmarking summarised in a positional mapping and a usability analysis. The implementations of these methods will be described in the following sections.

4.2.1 Benchmarking

The search for similar products to Eliq's app was done by searching for similar apps in the App Store, searching the web and by posting questions in two Facebook groups, one for solar panels and one for electric vehicles. Questions were posted asking if the members of the groups use any digital tools and if so, which one and how well it works. The Facebook groups used were *Solceller & solenergi forum och tips* (translation: Solar panels and solar power forum and advice) and *Elbil och laddhybridbil i Sverige* (translation: Electric vehicle and electro hybrid vehicle in Sweden). Previous posts by other members also contained useful information. During the search the focus was on apps and not websites, smart meters or other similar solutions. Furthermore the focus was on apps visualising electricity consumption, although apps solely focused on solar panels or electric vehicles were also investigated to some extent. The information gathered were mainly from the companies' websites, App Store and news articles. Apps from companies working together with Eliq have not been included. To sum up the findings of the benchmark, two positional maps were constructed with the apps analysed as well as Eliq's demo app. The characteristics used on the axises for the first map were *Serious-Playful* and *Simple-Cluttered*. In the second map *Serious-Playful* was instead combined with *Wide target group-Narrow target group*.

4.2.2 Usability Evaluation

The usability of Eliq's demo app was theoretically evaluated with the help of the 10 principles of useful design (Jordan, 1998). The app was thoroughly analysed focusing on one principle at the time. Notes were taken both when attributes and interactions were agreeing and not agreeing with the principles. Finally, conclusions were drawn on what could be changed and what should be kept in an improved version.

4.3 Findings

The result of the benchmark is first presented by a presentation of each application, followed by a list of functions which have appeared throughout the benchmark. Finally, two positional maps including the apps are presented.

4.3.1 Electricity monitoring apps

A variety of electricity monitoring apps were included in the benchmark presented in this section. However, apps from companies collaborating with Eliq in some way have not been included as they have similar design language as Eliq's demo app. They are furthermore not competitors, but collaboration partners.

Eliq

Eliq (logo shown in figure 4.1) provides software for electricity providers, to enable their customers to monitor their electricity consumption. They have a white-label app which compares information from electricity providers with factors like weather and smart home data, to provide smart analyses and forecasting (Eliq, n.d.). Their design uses rounded shapes and a lot of white with dashes of colour, mainly turquoise and blue. The information is often presented on cards. Figure 4.2 shows some examples of screens in the app retrieved from the demo app.

Figure 4.1. Eliq's logo.

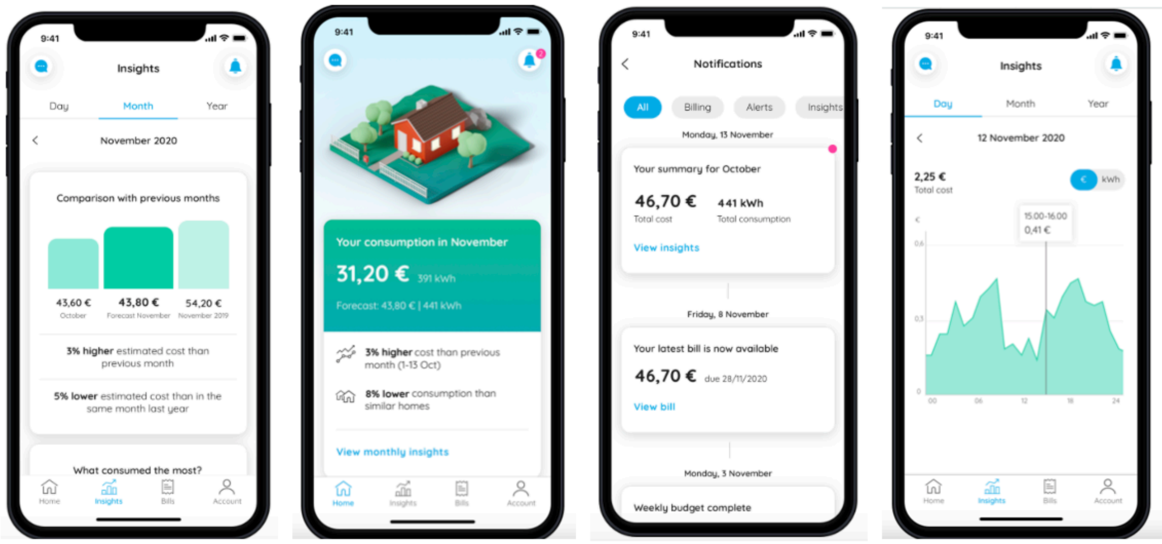


Figure 4.2 Eliq's mobile application.

Greenely

Greenely (logo is shown in figure 4.3) is an electricity supplier providing an app showing the electricity consumption. It is not necessary to be a customer of *Greenely* to use the app but customers have more available functions (Greenely, n.d.). Their design uses soft shapes and thick lines, with bright colours on a white background and fun and positive vibes. Figure 4.4 shows some examples of screens in the app retrieved from the App Store.

Figure 4.3. Greenely's logo.

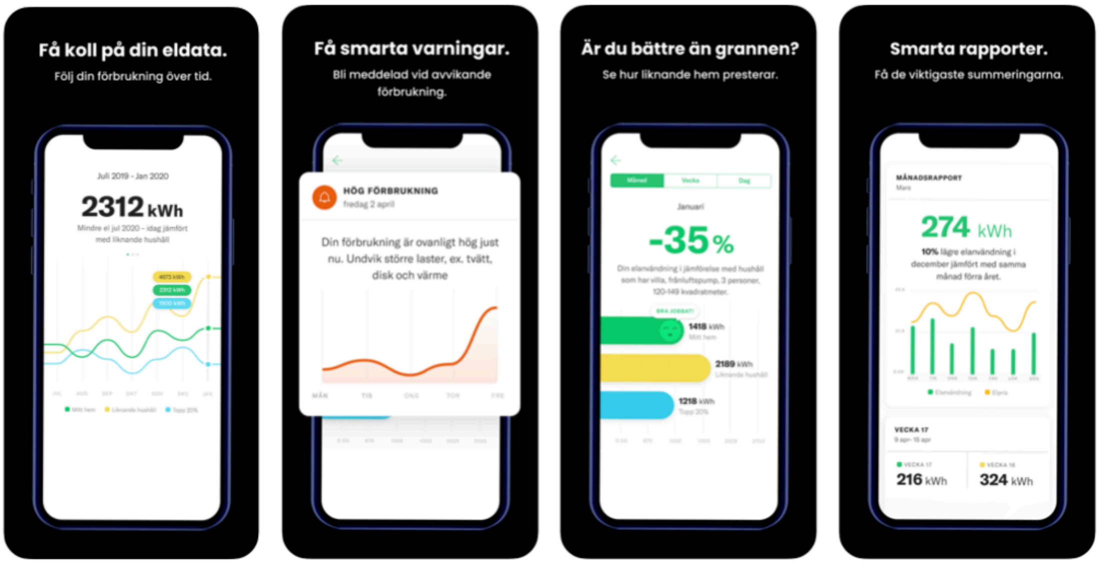


Figure 4.4. Greenely's mobile application.

E.ON

E.ON (logo shown in figure 4.5) delivers electricity, heat and smart energy solutions to households and industries in Sweden. The app is free to use for customers or households using their grid (E.ON, n.d.a). Their design is text-heavy with a lot of white squares. The colours used are mostly black and white with sporadic pops of red and desaturated turquoise. Figure 4.6 shows some examples of screens in the app retrieved from the App Store.

Figure 4.5. E.ON's logo.

Figure 4.6. E.ON's mobile application.

Tibber

Tibber (logo shown in figure 4.7) is a digital electricity supplier selling renewable energy at acquisition value per hour. Their application is available for their customers (Tibber, n.d.). Their design consists of rounded shapes with thin lines. The app is using desaturated colours and in many screens the text is white on a coloured background. Figure 4.8 shows some examples of screens in the app retrieved from the App Store.

Figure 4.7. Tibber's logo.

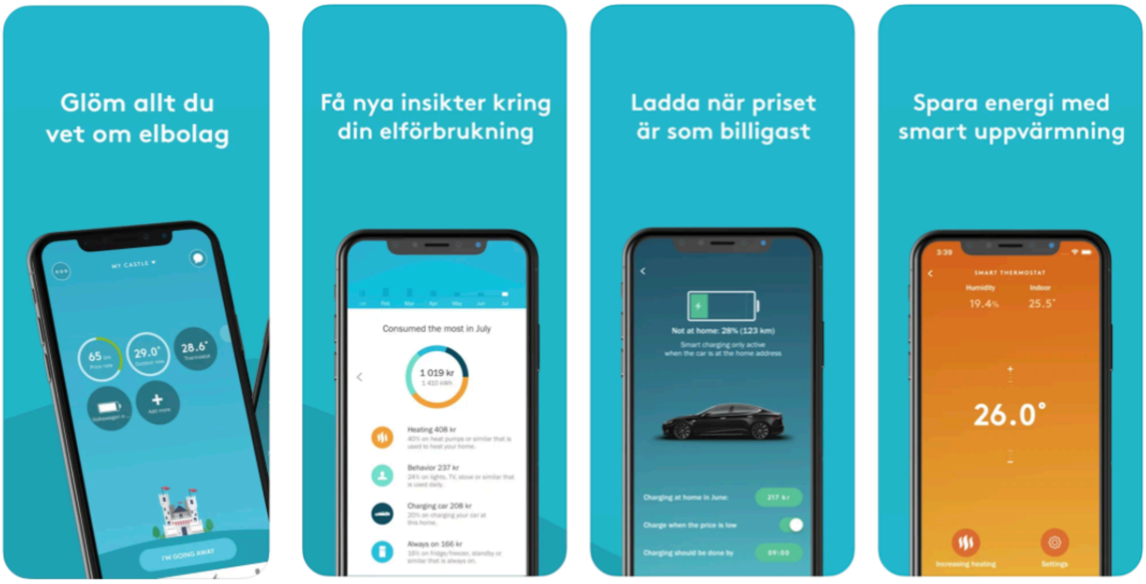


Figure 4.8. Tibber's mobile application.

Svea Solar

Svea Solar (logo shown in figure 4.9) is an electricity provider of solar energy, as well as a supplier of solar panels (Svea Solar, n.d.). The design is simple with mainly thin white lines on a blue background. From the screens retrieved from the App Store that can be seen in figure 4.10, it is a bit unclear how the navigation in the app works.

SVEA SOLAR

Figure 4.9. Svea Solar's logo.

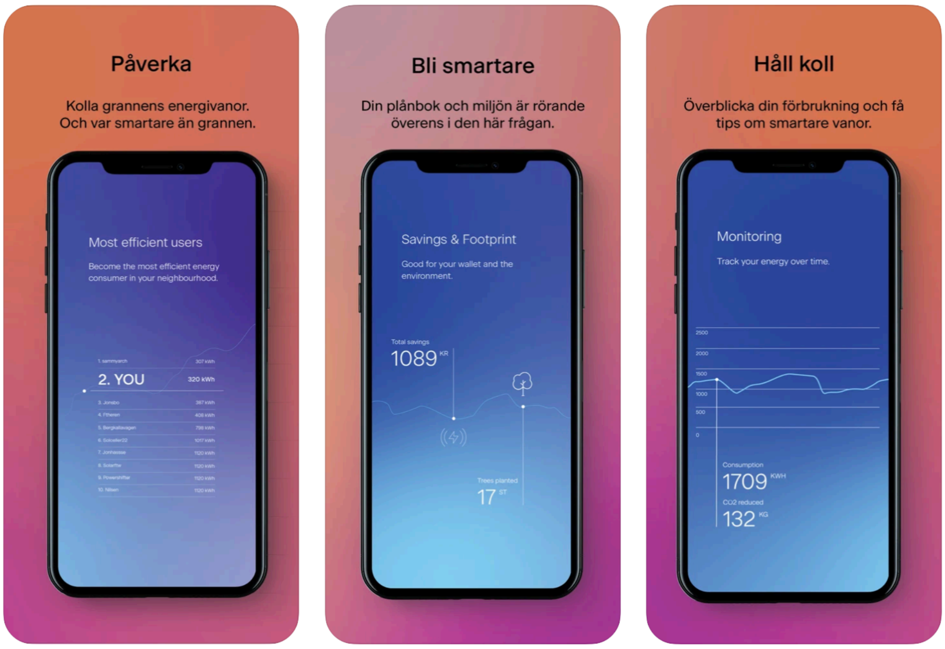


Figure 4.10. Svea Solar's mobile application.

Myenergi

Myenergi (logo shown in figure 4.11) provides energy control products, for example a charger for EV's and a solar power diverter. The app enables the user to control and monitor such devices (Myenergi, n.d.). The design uses rounded shapes and thin lines, with vibrant colours on a black background. The screens retrieved from App Store in figure 4.12 all give a tech-heavy and somewhat obsolete impression.

Figure 4.11. Myenergi's logo.

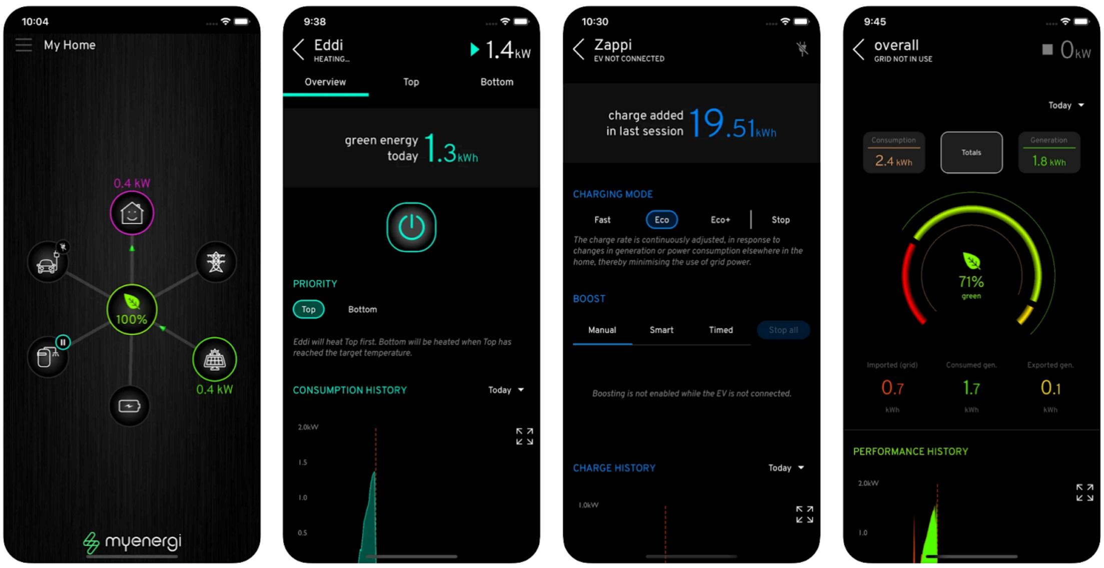


Figure 4.12. Myenergi's mobile application

ETC el

ETC el (logo shown in figure 4.13) is an electricity provider of renewable energy with focus on solar power. The company owns solar farms and also encourages and helps customers install solar panels (ETC el, 2016). The design mainly uses rectangular shapes with slightly rounded corners. The colours used are mainly different shades of red on a white background. Figure 4.14 shows some examples of screens in the app retrieved from the App Store.

Figure 4.13. ETC el's logo.

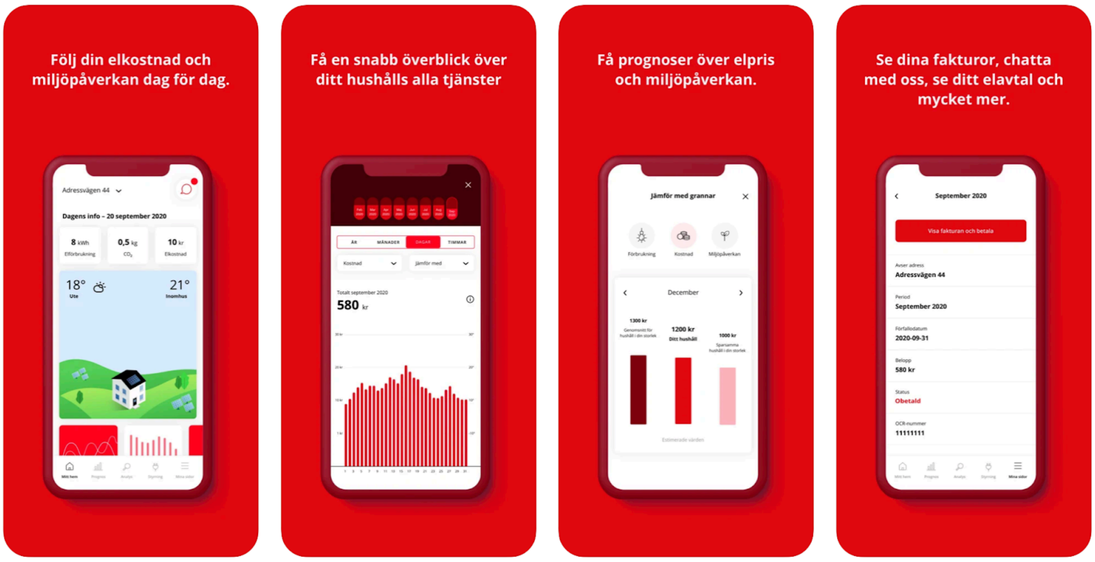


Figure 4.14. ETC el's mobile application.

4.3.2 List of functions

After the benchmarking had been summarised, a list of functions that appeared in the apps was established. The list contains functions that appeared in one or several apps, and will serve as inspiration further on in the project. It must however be noted that one must be customers to the electricity companies in order to get full access to the apps, so the functions listed are the ones that are possible to find without having real access to the app. This implies that there might be functions that have not been included, but are available to the customers. The functions across the apps presented in section 4.3.1 Electricity monitoring apps were as follows:

- Electricity consumption per hour
- Comparison with similar households
- Monthly and weekly reports
- Consumption comparison with previous time periods
- Price of electricity across the day
- Consumption so far this month
- Production from solar panels
- Advice on how to make better choices

- Personal to-do list
- Comparison with weather
- Map of charging stations for EV
- Access to invoices
- Information on electricity outages
- Choose when the EV will be fully charged
- Choose to what battery percentage to charge EV to
- Control heating and lighting of the house
- See how electricity flows between different components (e.g. grid, solar panels, house)
- Connect parts of the house and make it smarter
- Forecast on what the electricity consumption will look like in the future
- Set timers
- Info on when it is most effective to for example do laundry or charge the EV
- Encouragement via a chat-bot
- Information on what consumes the most in the house

4.3.3 Positional Mapping

The benchmarking was summarised in two positional maps where the different electricity monitoring apps were positioned on the maps according to different key attributes. The chosen attributes had been found to vary across the apps and be important factors in how they are perceived and what type of users they would be suitable for. The attributes *Serious Design* and *Playful Design* are used in both maps. The assessment was made holistically but bright colours and cartoonish figures for example were considered to give the apps a more playful appearance. Other attributes used are *Simple* versus *Cluttered* which refers to how densely packed the information is and *Wide* versus *Narrow Target Group* which is based on how many and what types of functions the different apps have and who can use them.

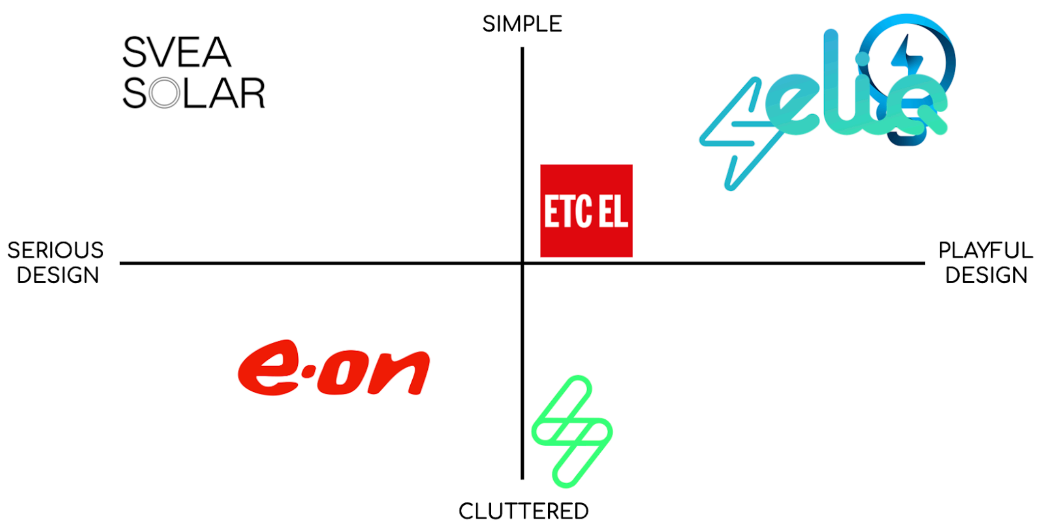


Figure 4.15. Positional map 1.

In the first positional map (figure 4.15) *Eliq*, *Greenely* and *Tibber* were considered to be simple with playful designs. They were colourful with some playful elements such as smileys or cartoon houses and they had a lot of empty space around the text or figures. *ETC el* and *Myenergi* were close on the *Serious-Playful* dimension but different on the *Simple-Cluttered*. Both had some very bright colours and were considered more playful than serious. *ETC el* was however more simple while *Myenergi* was more cluttered. *E.ON* was also considered cluttered and serious because of how dense and text-heavy it is. Lastly, *Svea Solar* was considered simple and serious because of its few and muted colours, thin lines and empty spaces.

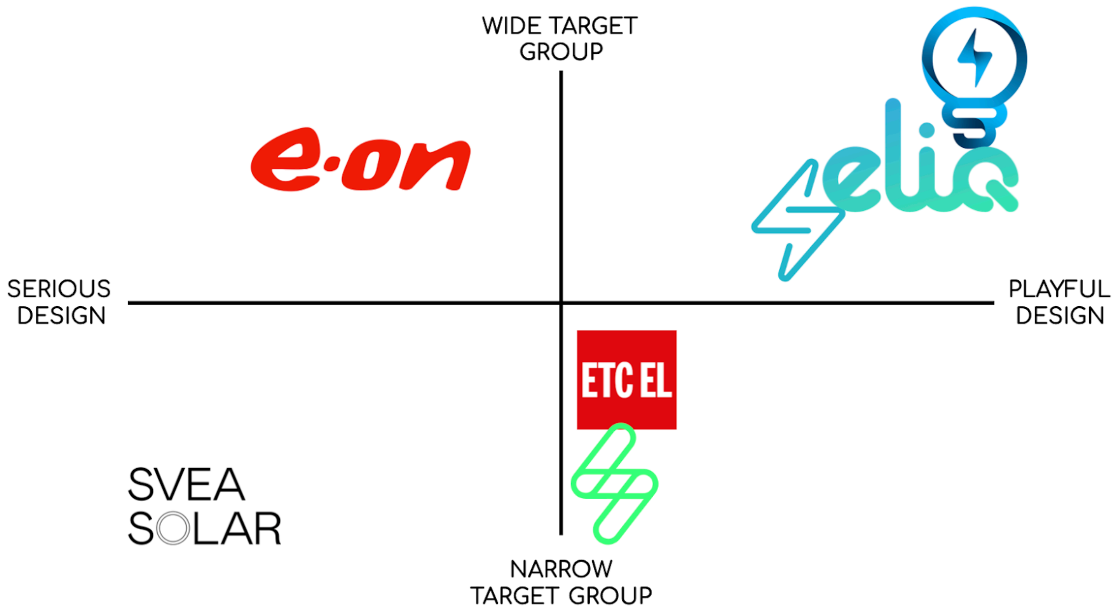


Figure 4.16. Positional map 2.

In the second positional map (figure 4.16) the apps were placed the same on the horisontal axis as the dimension *Serious-Playful* is the same. They have however been moved on the vertical axis as the dimension here is *Wide-Narrow Target Group*. *Greenely* was considered to have the widest target group as the app has many functions and is available for everyone, even those who are not customers. *E.ON*, *Eliq* and *Tibber* also have wide target groups and many functions, but with less availability, for example only available to customers. *ETC el* was considered to have a more narrow target group since it has various functions but is mostly focused on solar power. *Svea Solar* and *Myenergi* were considered to have the most narrow target groups since *Svea Solar* focuses on solar power and *Myenergi* on solar power and EV's.

4.3.4 Usability analysis

The usability of Eliq's demo app is generally good. The overall impression is that it has relevant functions and is easy to use. While some features of the app may go against the principles there is generally a reason for it. There are however still features that were found to have potential for improvement. A more detailed analysis of each principle is presented below. Worth noting is that the analysis is based on the demo app. How the app looks to the end user depends on several factors, for instance what colours the electricity retailer uses and what data they are able to offer.

Consistency

The design language is generally consistent with the font and colours used as well as the use of boxes with rounded corners. The purpose of the colours is also consistent with green being a contrast colour to the normal white background and used in bars and diagrams, blue being used to indicate that something is clickable or that an option or menu is chosen or activated and pink is used to draw attention to special events, as can be seen in figure 4.17.

The bottom menu is always visible except for when entering secondary pages from the home screen, such as *My Tesla* or *Thermostat*. In those cases a back arrow in the upper left corner is visible instead. While the disappearance of the bottom menu could be considered as an inconsistency the back arrow is consistent for those instances. Examples of this are displayed in figures 4.21 and 4.22.

There are recurring bar charts in several places such as the month and year view of consumption, *What consumed the most?* or the *Charging history* of the EV. The day view of consumption is a line diagram instead but while it could be considered inconsistent it is an appropriate way to visualise continuous consumption over time. The *Charging history* of the EV has bar charts for all time periods, including the day view, but since the duration of the charging spans over shorter periods of time it is reasonable to use bar charts instead of line diagrams even if that would be more consistent.

Dashed lines and lighter colours are used to visualise forecasts in the consumption diagrams (figure 4.18). In *Comparison with previous months* and *Comparison with previous year* however the darker green standard colour is used for forecast while the lighter colours are used to show previous months and years (figure 4.19).

The feature *What consumed the most?* (figure 4.20) is only available in the month view of insights, not for day view or year view. While it could be argued that the information is most relevant on a monthly basis it could also be valuable information to have for other time periods as well. If added it would also add another feature to the day view. Currently there is only the consumption diagram in the day view and it is therefore the only time period that is not scrollable.

In the diagrams a black line is used to show more detailed information on a chosen bar or time period (figure 4.18) despite the blue colour being used in other places to show when something is marked. This inconsistency could however be because black provides better contrast to the green colour used in the diagrams.

The options *Lowest* CO_2 *emission* and *Lowest cost* are used both in *Schedule smart charging* of the EV and *Smart thermostat* and the symbols used to visualise the options are consistent (see figures 4.21 and 4.22). The design language used for *Thermostat* is however less consistent as it deviates by having the graphics cover the whole page.

Pink to bring attention

Pink dot with a number show new notification

Standard way to switch between units

Bars are not chronological, dark colour show forecast and lighter colour show history

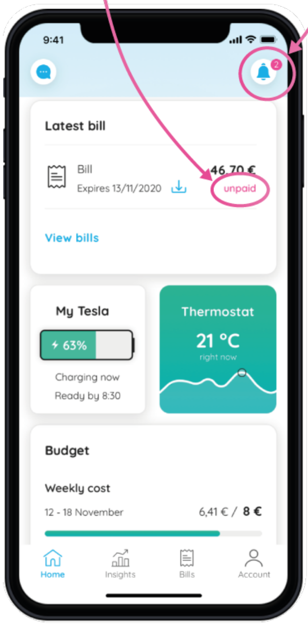


Figure 4.17. Eliq's app, homescreen

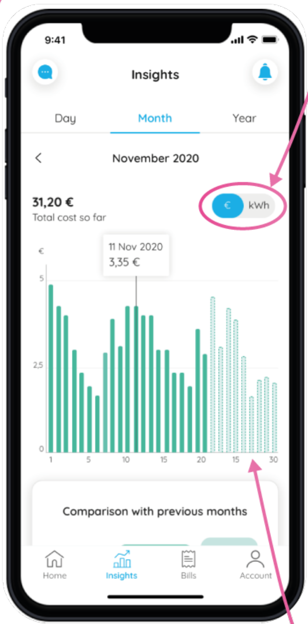


Figure 4.18. Eliq's app, insights

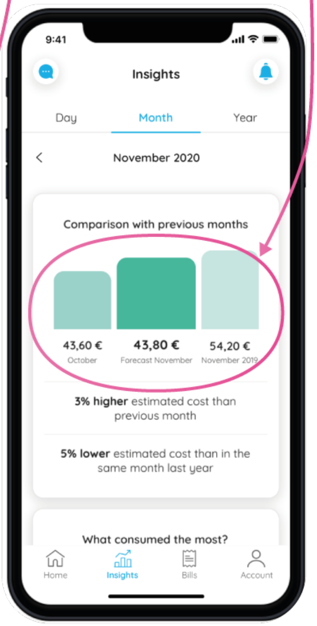


Figure 4.19. Eliq's app, insights

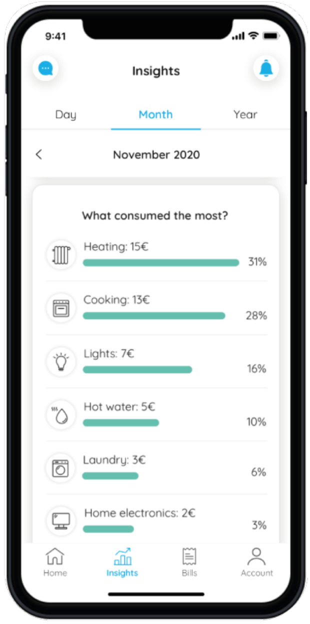


Figure 4.20. Eliq's app, insights

Lighter colour and dashed line for forecast

Arrows to go back

Pink to highlight new information

Size of text brings excessive attention, easily misinterpreted

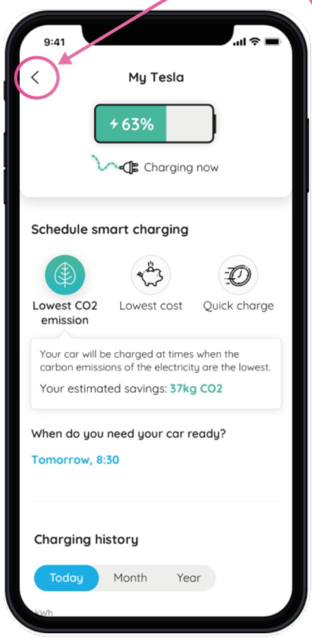


Figure 4.21. Eliq's app, My Tesla

Figure 4.22. Eliq's app, Smart Thermostat

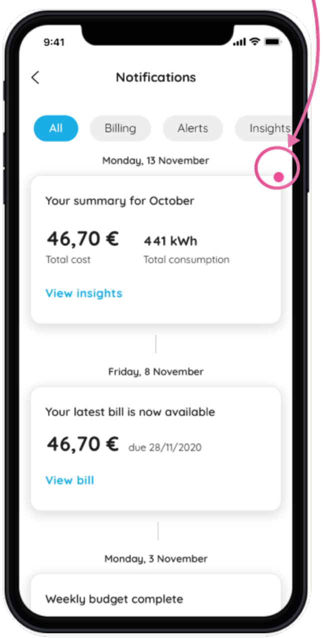


Figure 4.23. Eliq's app, notifications

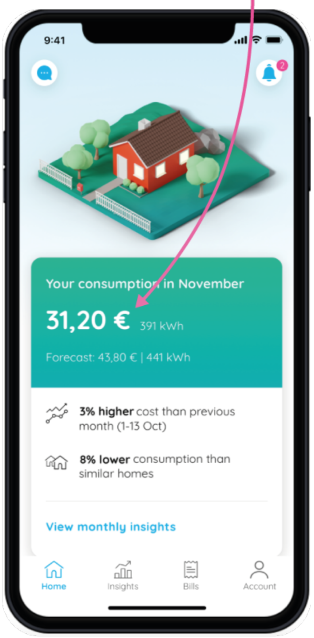


Figure 24. Eliq's app, homescreen

Compatibility

The compatibility is good overall. The symbols used, for example the symbols used to symbolise *Home*, *Bills* and *Account* in the bottom menu are easily recognisable and the bottom menu itself is also commonly used. The way the user can switch between Euro and kWh in the consumption diagram is also standard, this can be seen in figure 4.18. Most functions and graphics, for example the bars and diagrams, are also designed in similar ways as in other similar apps.

Consideration of user resources

The app generally has high consideration of user resources. While it is only visible information it is to be expected since it is the easiest way to show information in a digital format. The app shows one function at a time and is not cluttered.

Feedback

There are several instances when the app gives feedback. Notifications are given when there is a new bill, when there is a new monthly summary, if there is abnormal consumption and when there are updates on a set budget. Figure 4.17 shows what it looks like when a new notification has been received. Regarding the budget it is also possible to keep track of the progression. Consumption data are measured consistently and an increase or decrease in consumption shows up in the app almost immediately. When the user clicks on something and navigates between different screens, or chooses if the consumption will be shown in money or energy used, the changes happen immediately.

Error prevention and recovery

Error recovery is not a major problem. No serious harm can be done by mistakes done in the app and it is relatively easy to go back to previous settings if one regrets the decision or presses the wrong thing. It is however not possible to go back to previous settings except for manually changing them again. Being able to save settings could be one option to make this easier. When it comes to error prevention the main problem is that some functions require precise touches, such as clicking on the different bars to view consumption of different days in the month (figure 4.18).

User control

The app is more focused on showing the state of things than controlling them. The main control over what shows up in the app is done physically in the home. For instance if someone wants to see a decrease in energy consumption that person has to do those changes in the home before it shows up in the app. The user cannot control appliances through the app. It is however possible to adjust the thermostat or the charging of an EV through the app. The functions available for the EV may however be somewhat limited compared to other apps, especially apps focused on EVs. The changes that can be controlled through the app generally have to be initiated by the user. Overall there is a very low risk of the app taking action without the user's knowledge or the user losing control to the app.

Visual clarity

Visual clarity is overall good. The colours are clear against the white background and the fact that different colours are used for different things makes it even clearer. The different diagrams are easy to understand and have a high readability. The line diagram used in the day view for consumption is suitable for detailed visualisation of continuous change. It is also intuitive and easy to see that lighter colours with dotted lines are visualising forecasts in the diagrams (4.18). However, in the *Comparison with previous months* (figure 4.19) the bar showing previous month and the bar showing the same month previous year has similar light green colours and it is not directly apparent what the different bars mean without reading the text. The order of the bars could also cause confusion as they are not in chronological order.

Prioritisation of functionality and information

The menu at the bottom offers the easiest way to navigate between functions and includes *Home*, *Insights*, *Bills* and *Account*, which could be regarded as the most important functions. The home page is the first screen the user will see when opening the app and is therefore also important. The homepage may however benefit from some rearrangement.

The house at the top of the home page (figure 4.24) which is the first thing the user will see is not particularly important. While it may look cute and may reinforce the idea that it is the homepage, it does not provide any other new information. It appears to be a static image that does not change according to either changes in the household or external factors. Furthermore the house shown may not correspond to the owner's house. The benefits the house image provides may not warrant its size or location.

The first card with info, directly under the house image, with the title *Your consumption in November* (see figure 4.24) is at first glance somewhat unclear, as it is not obvious that the price is so far the current month and not a forecast or similar. It becomes clearer when reading the text but the text for forecast is very small compared to the price and may be overlooked.

Other functions placed in the home page are *My Tesla*, *Thermostat* and *Latest Bill* (figure 4.17). *My Tesla* and *Thermostat* can only be accessed through the home page and are equally placed but their importance differs. *My Tesla* is relatively far down even though the user is likely to interact with it frequently in order to charge the car. The EV function could be put higher up on the home page or even have its own menu at the bottom. The thermostat on the other hand is likely a function the user rarely interacts with. Furthermore, *Thermostat* draws attention to itself by being filled with a bright green colour, even though its importance may not warrant that degree of attention. On the other hand the latest bill and the shortcut to the bills page is relatively high up, above *My Tesla* and *Thermostat*, which may not be necessary since bills are already part of the bottom menu.

Appropriate transfer of technology

There is not much other technology from other contexts that can be utilised since it is a digital product. There is no problem with transfer of technology and the used technology works well.

Explicitness

The usage of blue text to indicate what is clickable as well as showing what options are activated and where the user is in the app helps the user understand what can be done in the app and how to achieve it. The symbols and verbal information also give explicit clues on what can be achieved.

4.3.5 Summary

It can be concluded that there are many similar electricity monitoring apps on the market. To differentiate oneself from the rest, it is crucial to offer something special or focus on making the functions extra appealing and trustworthy. Playful and simple designs for a wide target group are common factors for *Eliq*, *Tibber* and *Greenely*. Both *Tibber* and *Greenely* are companies that appear to be modern and innovative. To be positioned in the same clutter as them can be both beneficial and disadvantageous, as they might appeal to customers but it increases the difficulty to differentiate oneself.

This chapter has furthermore provided a list of functions that appear throughout similar apps. This will serve as inspiration when developing functions to be available in the new solution. Some important functions appearing throughout several apps might be crucial to be competitive and for customers to even consider choosing an electricity retailer, for example electricity consumption per hour.

Finally a theoretical usability analysis of the current solution was conducted. The usability analysis provided notes on both what should be kept and what should be altered in a future design solution. Conclusions were drawn that Eliq's demo app generally has a high usability, but that it can still be improved in some ways.

5

EXPLORATION

This chapter will present the explorative study, which was executed in parallel with the *ideation phase*. The explorative study consisted of a literature review, a questionnaire survey and interviews with some elements of co-design. In the following sections, the procedure and findings will be presented, as well as some conclusions that were the outcome of this phase.

5.1 Aim

The main purpose of the *Exploration phase* was to gain an understanding of household electricity consumption and what factors can affect electricity consuming behaviour. This understanding will lay the foundation on which the following development work is built and ensure that the solution is based on real users' needs.

5.2 Procedure

The methods used during the exploratory phase were a literature review on existing studies on the topics of interest, a questionnaire survey and semi-structured interviews with elements of co-design. To analyse the findings an Affinity diagram was conducted. The results were finally summarised in four personas. The implementations of these methods will be described in the following sections.

5.2.1 Literature review

The exploration was initiated with a literature review by searching databases to find relevant books and scientific articles. The purpose was to gain a broad knowledge base which would help both in planning the following research and providing inspiration and guidelines to the ideation phase. The main areas looked at were energy visualisation, energy consumption feedback, energy saving behaviour, data visualisation, solar panels and design for sustainable behaviour. To find relevant articles, Chalmers Library search function was used.

These articles were summarised and the most important findings were organised into four different categories that had been identified to be either overarching themes in several texts or inherently different from the rest. These categories were *prosumers*, *feedback*, *understanding* and *control*.

5.2.2 Questionnaire survey

A questionnaire was conducted in order to gain an understanding of people's behaviours and attitudes regarding electricity consumption. Compared to the literature study it was a more focused research, where the questions answered were relevant for this specific project and the respondents were part of the intended Swedish market segment. In order to ensure that people with solar cells and electric vehicles also participated, they were targeted specifically by posting the survey in Facebook groups dedicated to solar panels and electric vehicles. The Facebook groups used were *Solceller & solenergi forum och tips* (translation:Solar panels and solar power forum and advice) and *Elbil och laddhybridbil i Sverige* (translation: Electric vehicle and electro hybrid vehicle in Sweden). The survey was also shared with family and friends and in the Facebook group *Teknikkvinnor* (translation: Women in technology), to collect answers from the general public. The questionnaire received 165 answers in total.

The questionnaire was divided into four sections. For more information on all the sections and the questions included, see Appendix A. The first one contained more general questions about the household and their living situation such as type of housing, household income, number of people of different age groups in the household and what type of heating system they used. This was done in order to be able to see connections with other answers, as socioeconomic and demographic factors have been proven to influence energy saving behaviour (Martinsson, Lundqvist & Sundström, 2011). The second section included questions on electricity consumption, and included questions about for example awareness of electricity consumption, how they keep track of their consumption and what motivates them. The third section was dedicated for those who have solar panels installed on their house. Questions included in this section were for example if and how they monitor their solar power production and what motivated them to install a domestic solar power facility. The fourth and final section was dedicated to those who own an electric vehicle. Questions included in the final section were for example if they have access to an app or a website where they can get an overview of the charge and if and how they plan the charging. If the participant had both solar panels and EV, an additional question was provided. This was whether the production from the solar panels affects how and when they choose to charge their EV.

Some of the questions were open-ended for example what digital tools they use and how well they think it works, while some were closed-ended with multiple choice options, for example household income. Some of the closed-ended questions regarding feelings or attitudes were in the format of a Likert scale with a five point range. This makes it easier to see the strength of their feeling or attitude and also makes it easier to analyse numerically.

5.2.3 User interviews

The interview was divided into two parts. In the first part the purpose was to dig deeper about energy consumption, app and website usage as well as motivators regarding conservation of the environment. The second part was used to discuss images showing various ways of visualising certain functions in the app. This is further presented in 6.3. The sessions lasted approximately one hour, including both parts. Because of the current COVID-19 situation most of the interviews were held digitally through Zoom or Microsoft Teams. These programs were chosen rather than to just use phone calls in order to be able to see the participants' reactions and to be able to react more naturally.

Seven interviews with users were conducted. The participants had been chosen specifically to get a spread in ages and accommodation, to get both app users and non-app users and to include people who have solar panels and EV. Table 5.1 presents the participants in the user interviews. In some interviews with people in shared households more than one person was interviewed at the same time and they answered the questions together.

Table 5.1. List of participants in the user interviews.

	Nr. of people present	Type of user	Accommodation	Age span
User 1	1	Website user	Rental apartment	20-30
User 2	2	Invoice	Detached house	60-70

User 3	1	App user	Tenant owned apartment	20-30
User 4	2	Invoice	Detached house	50-60
User 5	1	Solar panels, website user	Detached house	60-70
User 6	1	Electric vehicle, website and app user	Detached house	20-30
User 7	1	Solar panels, invoice	Detached house	60-70

There were different interview guides made for the different types of users. The first part about electricity usage had different questions whether or not the participant used a website or an app to keep track of the electricity consumption or if they only paid the bills with an invoice. Questions for the participants who used a website or an app were for example how often they use the app and what information they usually look for. The participants who only use the invoice were asked for example if there is any information they would like to know that they cannot see on the invoice.

There were also special questions for those who owned solar panels or EV's, for example how they usually keep track of the electricity production and if they have a separate website or app for the electricity consumption or if they can see production and consumption in the same place. Questions specifically about EV's were for example if and how the purchase of the EV affected how they used electricity overall, and if and how they think about when to charge the car. To finish the first part of the interview they were all asked if there is anything else other than keeping the electricity consumption down that they do for the environment, what their biggest motivation is for doing so and what in nature they are most afraid of being lost or destroyed due to climate changes.

5.2.4 Expert interviews

In addition to the user interviews, two experts were interviewed to gain an understanding of the electricity and solar panel markets from the business perspective. The experts are presented in table 5.2.

Table 5.2. List of experts.

Expert 1	Salesperson of solar power facilities
Expert 2	Expert in the Nordic energy market

The interviews with the experts were more unstructured compared to the user interviews and it was meant to be more of a discussion, although some questions and topic areas had been prepared beforehand for Expert 1 and Expert 2 respectively.

The interview with Expert 1 was held over Microsoft Teams and lasted approximately 1 hour. The expert was first asked to briefly describe how solar panels work, and if the topics were not raised spontaneously further questions about for example factors influencing the production, taxes regarding solar panels, types of solar panels, and maintenance were asked. There were also questions relating to the expert's experience of selling solar panels, such as what people are interested in knowing before buying. There were also questions about the environment such as the environmental impact of production and recycling of solar panels and what the expert's thoughts were on the future prospects of solar panels.

The interview with Expert 2 was held over Google Meet and lasted approximately 45 minutes. The expert was first asked to describe how power tariffs work today, and how they are intended to work in the future. Topics regarding for example strain on the electric grid, electric vehicles and how the Nord Pool electricity market works were also discussed.

5.2.5 Affinity diagram

In order to analyse the result an affinity diagram was conducted, a photo from the session can be seen in figure 5.1. The first part of the interviews and comments from the questionnaire were printed out and cut into individual sentences or groups of sentences if the sentences were closely related and would be difficult to understand without context. The data was organised by categorising these parts together based on their relationship. As the categories were formed they were named based on the categories' characteristics. This was an iterative process where categories were renamed, divided or merged together when appropriate as new parts were put down or moved between categories. The final categories were:

- Invoice/statistics
- Distribution in household
- Want to see
- See in hindsight
- Comparison
- Feedback as motivation
- Cannot decrease/do not bother decrease consumption
- Environment
- Power shortage
- Lack of knowledge
- Motivation from environment
- Dissatisfaction with website
- Reasons to get solar panels or EV
- Production and sales
- Other reasons to decrease consumption
- Want to have electricity from renewable sources

The data in each category was then summarised and written in more general terms. Based on this information guidelines and insights connected to the categories were written down. The complete result of this analysis can be seen in Appendix B.

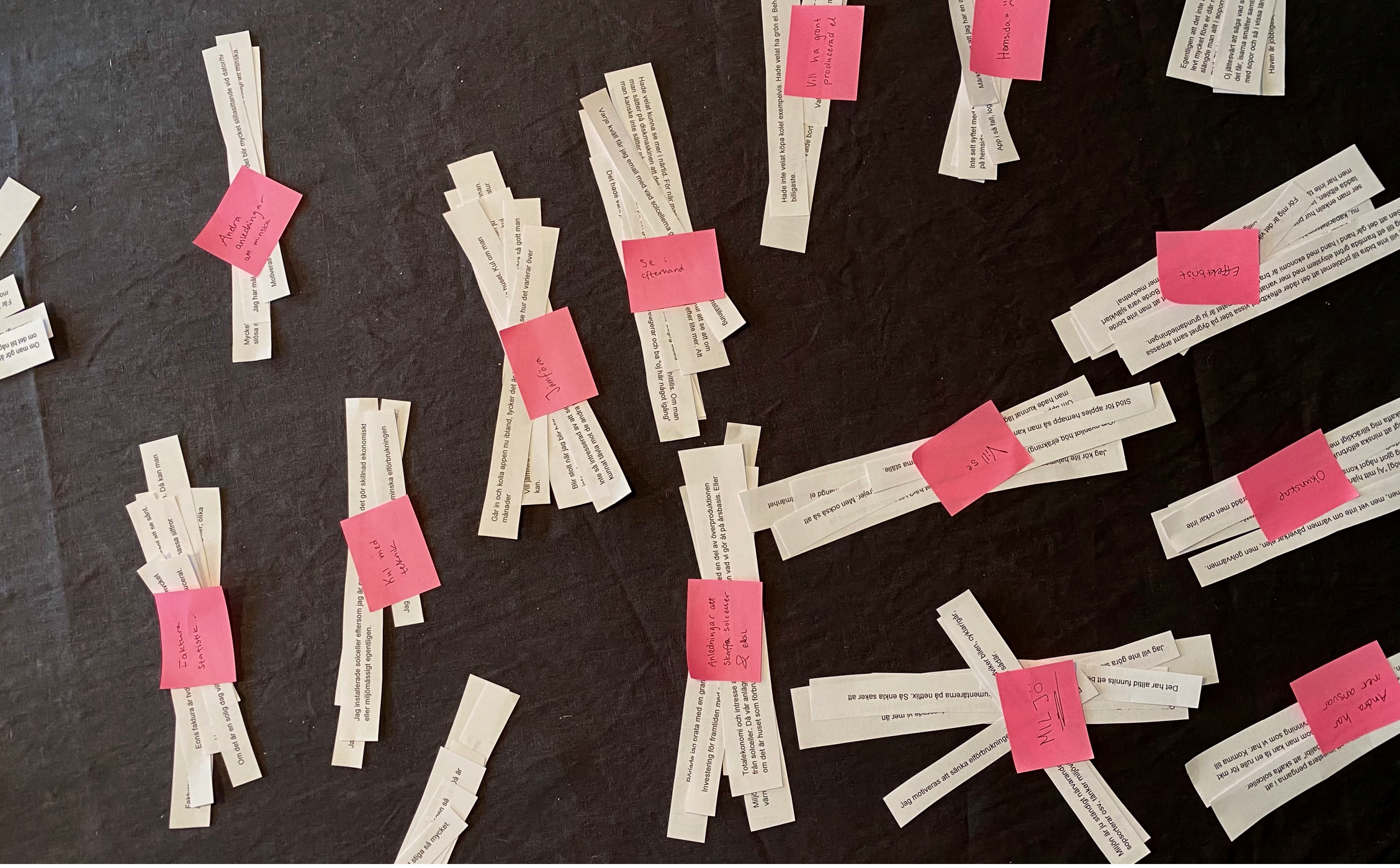


Figure 5.1. Affinity diagram, quotes from the survey and interviews have been grouped together in categories.

5.2.6 Personas

In order to focus the development work on humanised descriptions of target users rather than just a collection of data and statistics, four personas were created. They are meant to represent the real target audience based on the interviews and the questionnaire, which were analysed to find patterns, common traits and special needs. Each persona was made to represent different types of users, with varying demographics, traits and needs, and collectively they were meant to cover as many needs as possible. Some of the personas had more common characteristics in order to ensure that the solution would be suitable for the general public while some had more special needs in order to ensure that those needs were covered as well. To make the personas feel more like actual individuals they were given photos. Each persona was described with their age, occupation, family situation, type of housing and biggest motivator in trying to keep their energy consumption down. Their level of motivation to decrease consumption and their level of awareness of consumption was graded. A description of their lives and their attitudes and habits regarding energy usage was also made. Lastly, real quotes from the interviews which had inspired the creation of the personas were connected to them.

5.3 Findings

In this section, the result of the literature study and user studies are presented divided into themes. The literature study provided valuable insights into previous research conducted on the topic. The questionnaire survey provided a wide range of respondents, which resulted in statistics and connections between groups of users based on socio-demographic factors being attained. The following interviews were more qualitative and enabled reaching users' deeper emotions and thoughts on electricity. In addition to the user interviews, two experts were interviewed to attain an understanding for the electricity and solar panel markets from the business perspective. Furthermore, the expert interviews provided explanations to complicated questions and connections and a deeper understanding were attained.

5.3.1 Information format

In total the survey got 165 answers, of which the majority of the participants did not keep track of their electricity consumption or only pay the monthly invoice. Furthermore, 14 % used a website and 23% used a mobile app. There were also some respondents who monitored via a smart meter installed in their home. A smart meter measures the electricity consumption, sends the information to the electricity supplier and shows the information on an in-home display (Cassels, 2021). Lastly, a few used some other method to keep track of their consumption, for example an Excel spreadsheet. The division of how the respondents communicate with their electricity retailer and thereby keep track of their electricity consumption is shown in figure 5.2.

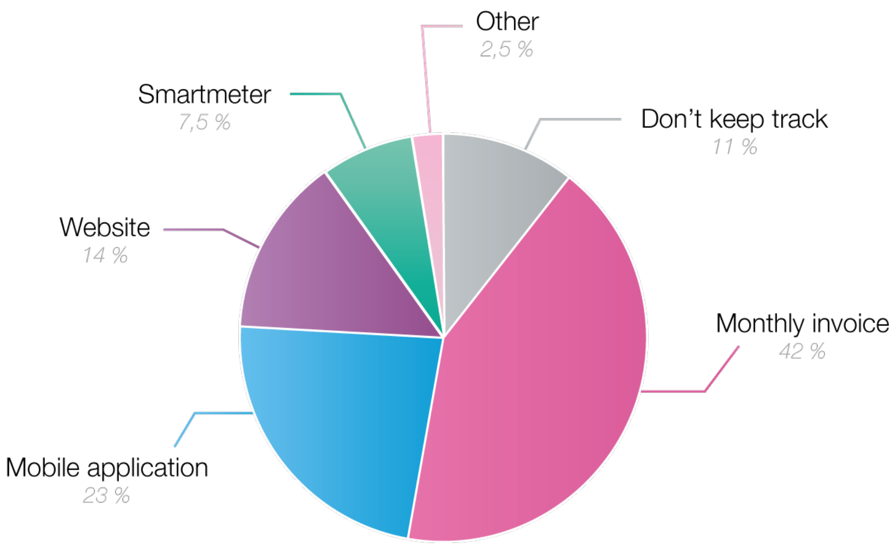


Figure 5.2. What tools respondents use to monitor electricity consumption.

Vassileva, Dahlquist, Wallin & Campillo (2013) mention that using direct feedback (in their case, an in-home display) could help the consumers save 15% of electricity, in comparison to indirect feedback (monthly invoice) which would only help them save 10%. The questionnaire conducted in this thesis project came to similar conclusions when comparing mobile applications (direct feedback) and monthly invoice (in-direct feedback). An analysis conducted by Eliq (2020) found that customers who used a smart energy monitoring app reduced their consumption on average 6,8 % compared to before using the app. The study conducted in this thesis project found that people having access to a mobile application to keep track of electricity consumption are more aware of their consumption (figure 5.3a). Furthermore they feel like they can affect their energy consumption to a larger extent compared to consumers only having access to the invoice (figure 5.3b). Although not investigating the actual effect on the consumption, it can be assumed that being aware of one's energy consumption has a positive effect on it. This is further supported by the result that app-users feel that they can affect their consumption to a larger extent. This was summarised well by User 4 who stated *"when the bill arrives it's too late to make adjustments"*.

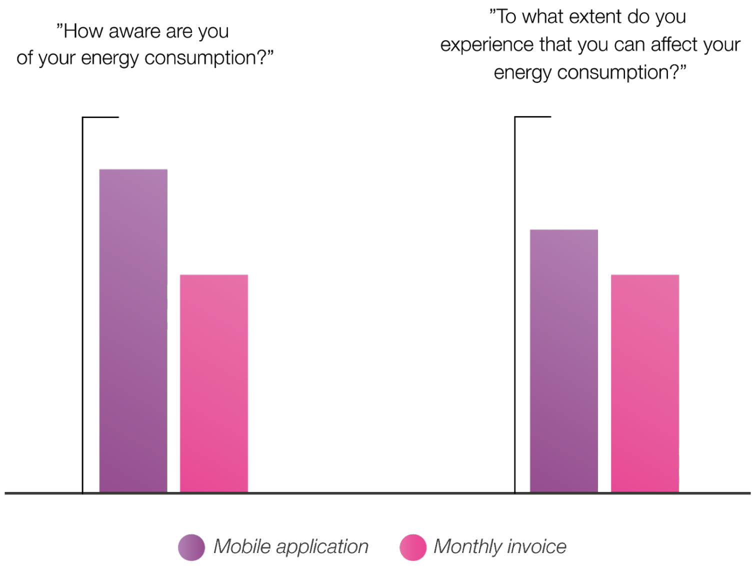


Figure 5.3a. How aware the respondents are of their electricity consumption.

Figure 5.3b. To what extent respondents believe they can affect their consumption.

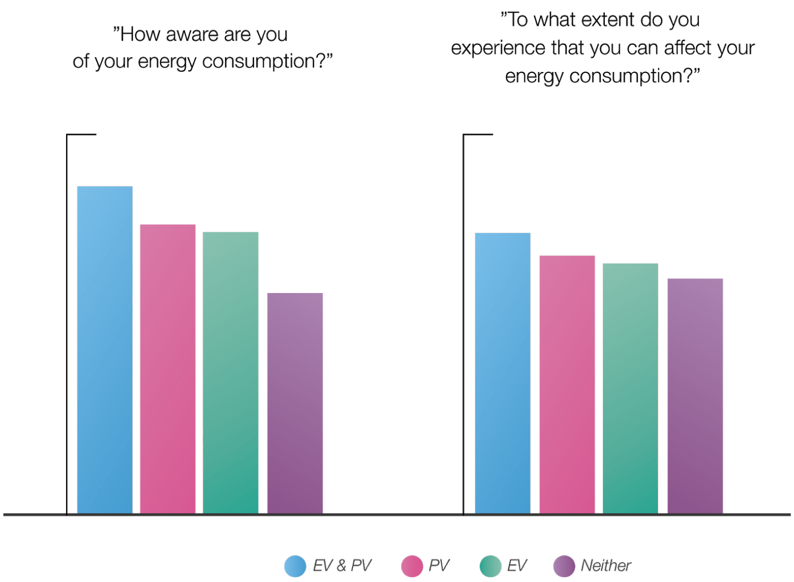


Figure 5.4a. Comparing awareness of respondents with EV, PV, both and neither.

Figure 5.4b.Comparing feelings of control of respondents with EV, PV, both and neither.

It was also found that prosumers and EV drivers feel they are more aware of their consumption and that they can affect their consumption to a larger extent than people having neither. Furthermore, people being both prosumers and EV drivers assigned a higher grade than the others on both questions. The result is shown in figure 5.4a-b. Furthermore it was found that 57% of the people driving an EV and 79% of people having solar panels use an app to monitor the electricity flow. This can be compared to only 29% for the whole group. This aligns with the result that app-users feel more aware and feel like they can affect their consumption to a larger extent. However, it cannot be concluded if it is the use of an app, or the owning of solar panels and EV that is the cause of the high awareness. It can however be assumed that both EV drivers and prosumers are more engaged, and might also have a higher need to monitor the flow of energy in their homes.

5.3.2 Socio-demographic factors

The results from the questionnaire show that demographic and socioeconomic factors affect how people think and act regarding energy consumption, which is supported by Martinsson et al. (2011). They conclude that age, housing type and income are the most important socio-economic factors influencing the degree of energy saving. These factors will therefore be discussed in the following sections.

Income

From the questionnaire it was found that the household's income influences why they think it is important to keep their energy consumption down. Low-medium income households put a higher importance on economic reasons than high income households. Figure 5.5a shows the distribution of motivators for lower income households. High income households instead put the highest importance on the environment. Figure 5.5b shows the distribution of motivators for high income households. Out of the participants answering the questionnaire, 43 % had a net income considered high.

The limit was set to 60 000 SEK per month for households with two adults, and 40 000 SEK per month for households with one adult. For comparison, the mean brutto income in Sweden was 35 300 SEK per month in 2019 according to SCB (2021). The total income for the household is higher if there are more people earning money in the household and also if the household is eligible for different benefits such as child benefit or housing benefit. For an average salary the municipal tax is the most significant tax which on average stands at 32,27 % in Sweden (Ekonomifakta, 2021). For a household of two people with average incomes living in for example Gothenburg (municipal tax of 32,6 %) the net income for the household is 53 520 SEK (Statsskuld, n.d.).

The division of income groups was decided partly upon the main income level in Sweden, and partly upon the division of possible answers in the questionnaire. The intervals in the options in the questionnaire on the question on net income were set to for example 20 000-40 000 SEK and 40 000-60 000 SEK, hence making it impossible to know the exact income of households. The decision to have intervals had previously been decided on as income can be a sensitive topic for many people, and also it might be difficult to know the exact number.

When households whose income were lower than 60 000 SEK were asked what their biggest motivation is for trying to lower their energy consumption, 29 % answered economic reasons compared to 24 % in the higher income group. The environment was said to be the most important by 37 % in the low-medium income group and 46 % in the higher income group. Both the economy and environment were mentioned as the most important factors by 28 % in the lower income group and 24 % in the higher income group. There were also some people in both income groups who stated that they consider not straining the grid as the most important. Furthermore there were some people who mentioned other reasons such as health or interest in technology as their biggest motivators.

Martinsson et al. (2011) support the claim that lower income groups put a higher importance on the economy and they also argue that income levels affect energy saving behaviours. They conclude that lower income households have a higher incentive to keep down the cost of electricity than higher income households where the economic gain from energy conservation may seem less important.

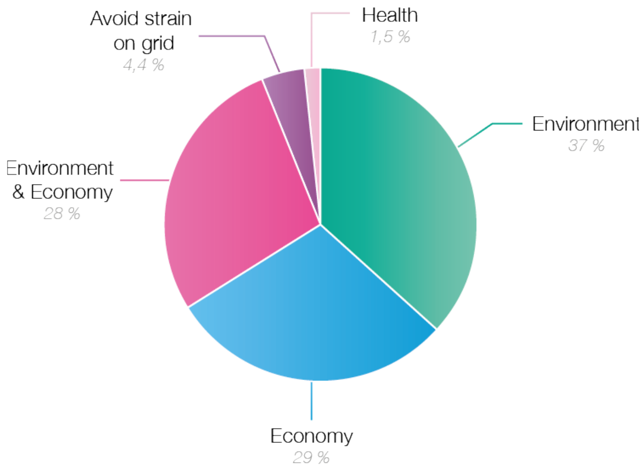


Figure 5.5a. What motivates low income households to decrease energy consumption.

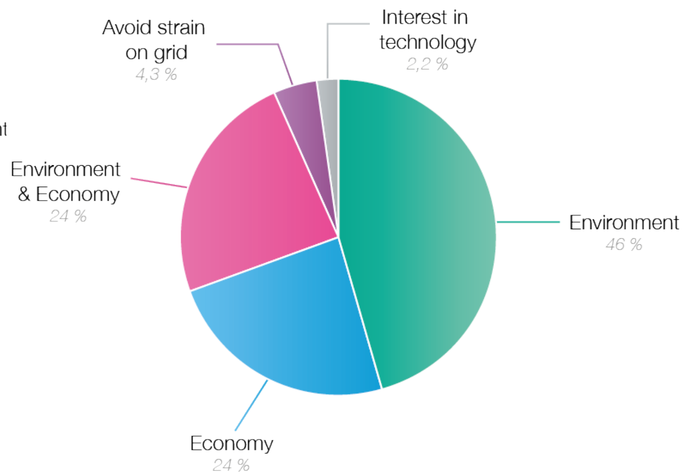


Figure 5.5b. What motivates high income households to decrease energy consumption.

From the survey it was also investigated whether income levels affect if people buy solar panels or EV's. It was found that there was a significant difference for EV's, where higher income groups were more likely to own one, but only a very small difference for solar panels was found. In the lower income group 27 % answered that they own an EV compared to 52 % in the higher income group. Even if the market for EV is growing, EV's are still relatively expensive and the high price is a hindrance for many (Augustsson, 2020). Interestingly, the difference in cost between an EV and a petrol car over a lifetime is decreasing and close to disappearing as the operating cost for an EV is lower, but the high purchase price is likely to make EV's a nonviable option for lower income households.

For solar panels on the other hand, 25 % of respondents from both groups had solar panels installed. One reason for this could be that although solar panels can be quite costly to install it is also an economic investment, which would be desirable for lower income households too as long as they can afford the initial cost. The total price of installing 10 kW solar panels on a normal sized detached house (a rooftop of 50 m2) is around 165 000 SEK, including installation but excluding price reduction. For solar panels installed in Sweden it is possible to get price reductions on the labour and material cost, which lowers the cost with about 15 % (Solcellskollen, n.d.). The payback period for solar panels is on average 10 to 14 years, meaning that after that time the initial outlay of the investment has been recovered through savings and cash inflow generated by the solar panels. Solar panels generate revenue by decreasing the amount of purchased electricity and by selling the surplus to an electricity retailer (Ahrlberg, 2021).

There is a possibility that the result from the questionnaire may be showing a higher degree of solar panel and EV ownership than the national average, as these groups were targeted specifically. However, the answers given from these groups about other topics such as income and motivators should be fairly representative.

Family situation

Households with and without children were compared to investigate whether the family situation affects the households' electricity consumption. Only participants living in detached houses were included in the analysis to make the user groups more comparable. It was found that there was no noticeable difference if the household had younger children (10 years or younger) or teenagers (11-17 years), or both. Households with any member younger than 18 have therefore been included in the *Household with children*-group. It was found that households without children believe themselves to be more aware of their energy consumption and experience that they can affect their consumption to a larger extent compared to households with children. This is shown in figures 5.6a-c. This finding is supported by Kjeldskov et al. (2015), who found that the current family situation greatly affects the households' ability to affect their consumption. To make an effort to shift the energy consumption would be time consuming and would affect everyday life. However, they stated that it was considered especially difficult with younger children, which contradicts the finding in this thesis that the age of the children was of less importance.

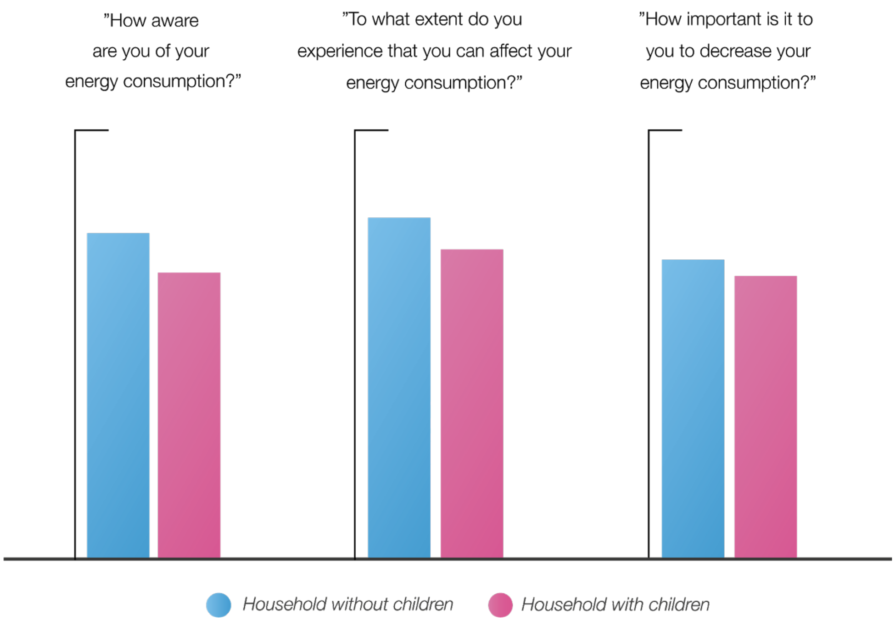


Figure 5.6a-c. Comparison between households with and without children regarding awareness, control and whether they consider it important to decrease consumption.

Several participants mentioned kids which can be summarised in what one of them stated, "*I think it's difficult to affect our electricity consumption with kids...*". Another participant said that "*I struggle to get my kids to turn the computer off when they are done using it*". It might be that some parents to younger children lack time and energy to care about energy consumption, and some parents to older children are met with resistance and ignorance when they tell their children to stop wasting energy. This must however be investigated further to be able to draw conclusions.

When asked how important it is to them to decrease their energy consumption, households without children stated that it was slightly more important to them than households with children. This is shown in Figure 5.6c. The difference is however almost insignificant.

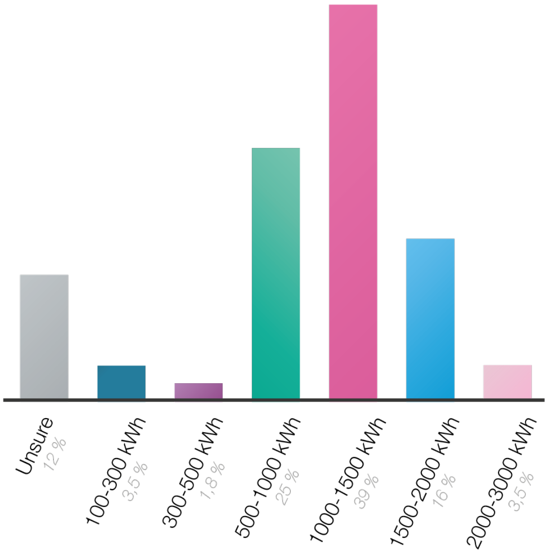


Figure 5.7a. Monthly electricity consumption, with children.

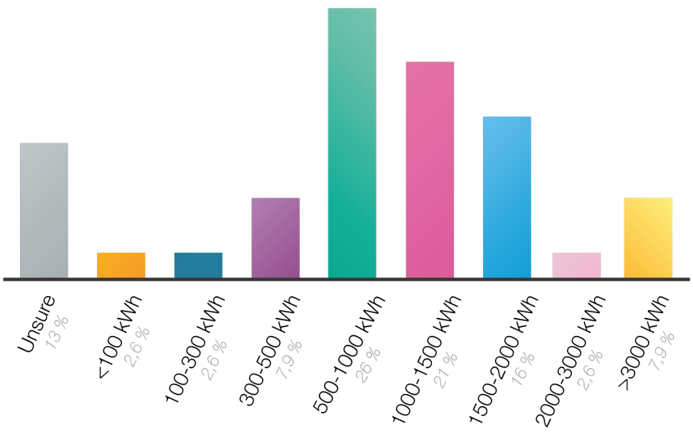


Figure 5.7b. Monthly electricity consumption, without children.

The total energy consumption of households living in detached houses with and without children were compared to be able to investigate the actual difference. The result is shown in figures 5.7a-b.

From figures 5.7a and 5.7b it can be seen that the share of participants being "unsure" of their energy consumption is 13 % (without children) and 12 % (with children) respectively. This is interesting since it disagrees with the findings shown in figure 5.6a. The previous result showed that households without children were more aware of their energy consumption compared to households with children, which is not true based on the latter result. More households from the first group were unable to report their monthly electricity consumption.

When comparing figure 5.7a with 5.7b it can be concluded that even though the consumption varies to a larger extent for households without children, households with children have an overall higher electricity consumption. 58 % of households with children have a monthly electricity consumption which exceeds 1000kWh, compared to 47 % for households without children. Both User 2 and User 4 mentioned that they had noticed a decrease in electricity consumption when their children moved out, and also mentioned that there are less variations in the consumption now. The lower consumption for households without children could be because it is more difficult to control the consumption, but it would also be a natural consequence of their household consisting of less people. Furthermore, there are plenty of other factors affecting the consumption, for example the size of the house and what type of heating is used.

A surprising finding was that 7,9 % of households without children consumed more than 3000 kWh per month, compared to those with children where no one consumed more than 3000 kWh. This contradicts the previously discussed finding that households with children consume more electricity than households with children. When investigated further, it was however found that the people stating they used more than 3000 kWh per month either had electric vehicles or a solar power facility. It was found by Li et al. (2020) that even though prosumers use 17% less from the grid their daily average of electricity consumption is 24 % higher than people who don't produce their own electricity. This would explain the households' higher consumption. Furthermore, one household had more than two adults living in the house, which resulted in a higher consumption even though no one of the people living there were children.

Accommodation

One important socio-demographic factor affecting how people view electricity consumption was believed to be whether they live in an apartment or in a detached house. Out of the respondents living in apartments, 42 % lived in tenant-owned apartments, and the others rented their apartments. No significant difference was found between these groups in terms of awareness or how much they believed they could affect their consumption, which is why they have been combined in figure 5.8a-c and 5.9a below. There was however a difference in how many that were "unsure" when asked about their monthly electricity consumption. For the participants living in tenant-owned apartments, 41 % were unsure about their consumption while 55 % of the participants renting their apartment were unsure about their consumption. The collective result for all participants living in apartments are shown in figure 5.9a. Martinsson et al. (2011) stated that tenants in rental apartments lack technical opportunities to save energy, compared to households who own their housing, who can purchase energy efficient appliances to a larger extent. This was also a problem that emerged during the study for this thesis as participants living in rental apartments felt limited in what actions they could perform in order to save energy, and it was stated by one participant that "*I rent my apartment, so I can't replace the large domestic appliances for more energy efficient ones*". It is believed that tenants in owned apartments to a larger extent are able to affect their consumption compared to those in rental apartments, which is why they are also to a larger extent aware of their consumption. The same tendencies are evident when comparing the answers of those living in a detached house with those living in apartments overall. The respondents living in a detached house are to a larger extent aware of their consumption as can be seen in figure 5.8a. This could be because they are more responsible for their housing compared to those living in apartments. Furthermore, they also experience that they can affect their energy consumption to a larger extent (figure 5.8b), and it is more important to them to decrease it compared to those living in apartments (figure 5.8c). This might partly be because a detached house demands on average more electricity than an apartment.

It was furthermore found by Martinsson et al. (2011) that people who own their homes tend to react stronger to economic motives, compared to people renting apartments who react stronger to environmental motives as the financial gain is smaller. When analysing the answers from the questionnaire survey conducted in this thesis it was found that economy and environment were equally important motives to decrease electricity consumption to the respondents living in detached houses. People living in apartments mentioned the environment as the most important motive 56 % of the time, compared to economy only being mentioned 38 % of the time. The statement by Martinsson et al. (2011) that people in rental apartments to a larger extent react to environmental motives can thereby be confirmed by the study conducted for this thesis.

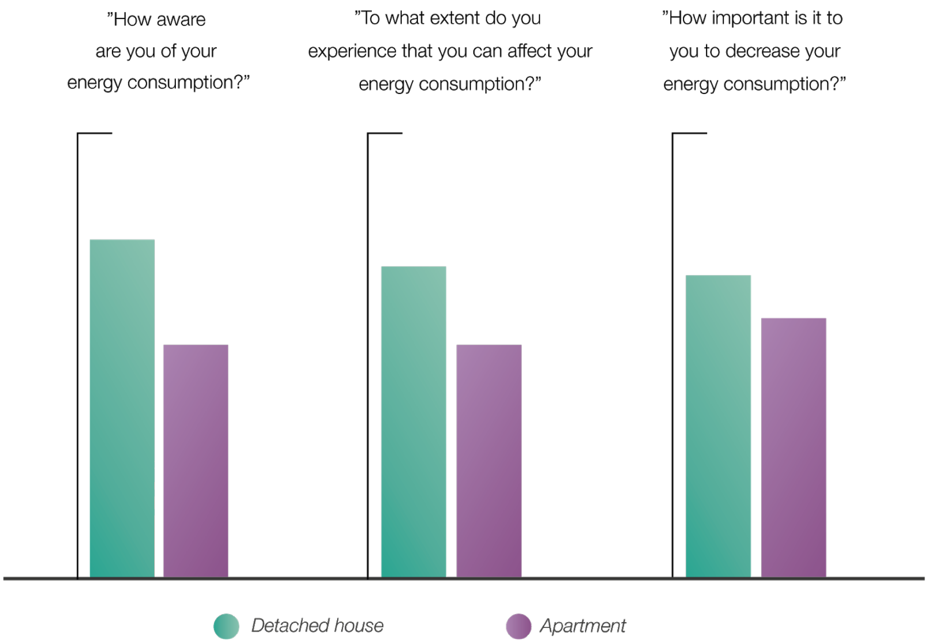


Figure 5.8a-c. Comparison between households in detached houses with households in apartments regarding awareness, control and whether they consider it important to decrease consumption.

When comparing the monthly consumption for people living in an apartment with house-owners, the difference is evident. Of those living in an apartment, almost half do not know how much energy they consume each month. This uncertainty is much smaller for those living in a detached house. Furthermore, the monthly electricity consumption is significantly higher for those living in a detached house. This is likely due to detached houses being larger than apartments and thereby demanding more electricity for heating. According to Konsumenternas Energimarknadsbyrå (2020a), an apartment uses approximately 2000 kWh per year. This does however not include heating, as heating is often included in the rent or charge when living in an apartment. For detached houses on the other hand, the typical yearly electricity consumption is 20 000 kWh if electricity is used for heating. If district heating or other types of heating is used, the yearly consumption is approximately 5000 kWh. A yearly consumption of 2000 kWh corresponds to 167 kWh monthly. 30 % of the respondents in apartments use 100-300 kWh each month, which is the largest share, as can be seen in figure 5.9a. A yearly consumption of 5000 kWh corresponds to 417 kWh monthly, and 20 000 yearly corresponds to 1667 kWh monthly. As can be seen in figure 5.9b the great majority of those living in detached houses use between 500-2000 kWh per month. The heating used has however not been analysed, and conclusions based on the effect of that can thus not be drawn. It must also be noted that the monthly electricity consumption varies greatly between the seasons, especially between summer and winter. This study was conducted during early spring, which could have affected the respondents to assign a higher consumption than what they would have done if asked during other seasons.

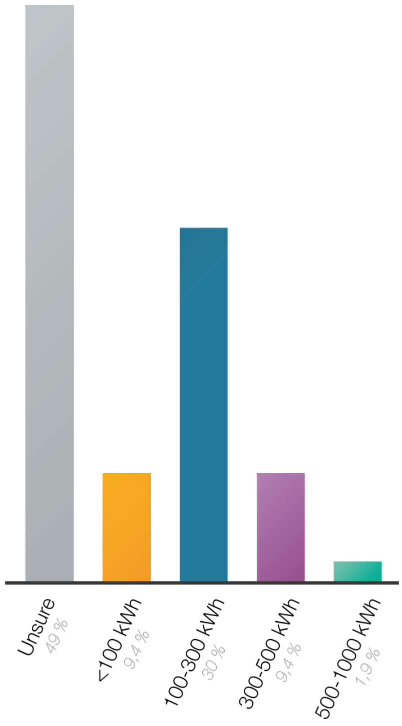


Figure 5.9a. Monthly electricity consumption, apartment.

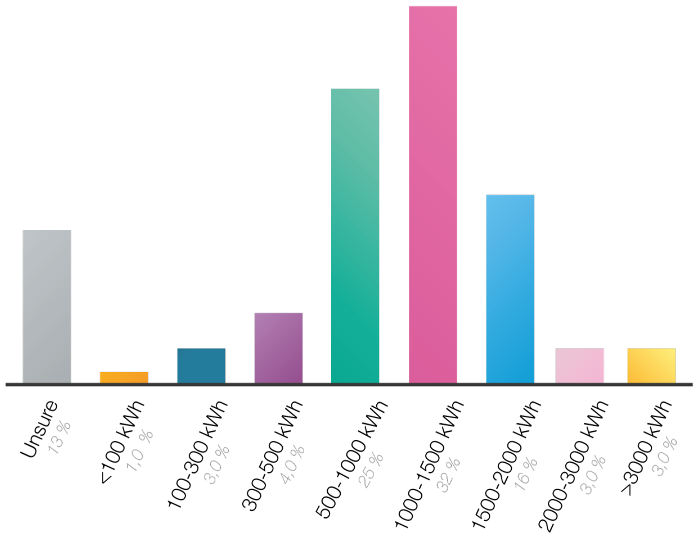


Figure 5.9b. Monthly electricity consumption, detached house.

5.3.3 Feedback

As could be seen in chapter 4 *Market analysis*, both Eliq and similar apps rely heavily on feedback as the information they provide on energy consumption. In the context of energy consumption, feedback refers to how the information about energy usage is collected and presented (Suppers & Apperly, 2014). However, there are many different visualisation and feedback techniques and how useful feedback is in motivating people to lower their consumption varies depending on several factors.

Direct and indirect feedback

Feedback can be both direct and indirect (Suppers & Apperly, 2014). With a direct feedback approach the energy usage is shown in realtime and the focus is on raising awareness. It is important however that there is no confusing or misleading information, as that can have a reverse effect and make consumers use more energy. It has also been found that some people find units of measurement such as kWh meaningless. Chetty, Tran & Grinter (2008) suggests that alerts which would notify the user when the consumption is abnormal or unusually high would be more useful. With indirect feedback previous consumption information is aggregated (Suppers & Apperly, 2014). One common example is the monthly electricity bill which shows the consumption and cost of the previous month. This type of summarised information can be useful for comparisons and for evaluating the effect of changes in appliances or change in behaviour. However, if only aggregated indirect feedback is being used it is insufficient for users to change their behaviour. People participating in the interviews also expressed their dissatisfaction with their monthly bills as they were considered complicated, insufficient and too far behind in time to provide useful information. User 3 expressed this as *"The invoice doesn't tell me very much"* and user 4 as *"What you actually see [on the invoice] is just in hindsight, and then it's too late!"*.

Techniques to change behaviour

Suppers and Apperly (2014) provide a range of techniques that can be used to make people use less energy. The most widely used method is to simply provide information. For example, encouraging positive environmental behaviour can be done by providing information about; *sustainability concerns* such as the decline of fossil fuel, *environmental impact* like the CO_2 emissions caused be the energy consumption and its effect on the environment, *savings* that can be made by using less energy and lastly, various energy saving *tips* as tips are a good way to give information to the user. In the studies conducted for this thesis there were participants that said they were unsure of how much they consume, its environmental impact and what they could do to most efficiently lower or further lower their energy consumption. This suggests that providing information would be helpful for these people.

Vasileva et al. (2013) stated that letting the consumers set their own consumption goal is one of the most effective strategies for increasing energy saving behaviour. Suppers and Apperly (2014) further acknowledge this and explain that goal-setting is effective because of four reasons; it is *directive* and directs people's attention to goal-related activities, it is *energizing* and gives people vitality and enthusiasm to act a certain way, it can increase people's *persistence* and lastly it is *indirect* and can indirectly make people better at accomplishing their goals.

Incentives, disincentives, rewards and penalties can also be used to encourage or discourage a certain behaviour (Suppers & Apperly, 2014). Incentives and disincentives precede an action while rewards and penalties are consequences of an action. Rewards are a type of positive reinforcement which can be given for instance when energy consumption is low in the form of for example gaining points or unlocking new content. Conversely, penalties or punishments can be used to reduce an undesired behaviour. It is done by letting undesired behaviour be followed by undesired effects such as the user losing points, rank or receiving an unpleasant message or image.

Another technique that Suppers and Apperly (2014) discussed was comparisons. Comparisons can be both self comparisons, such as comparing current consumption with historical consumption, and social comparisons where the user can compare their energy usage with friends or with the community. Both versions have their advantages but in general comparisons are a good method to motivate people to lower their energy consumption and can be used as a reference point. An advantage with social comparisons is that they allow for more competition and cooperation between different households. However, there are some aspects that need to be taken into consideration. Chetty et al. (2008) also pointed out that social comparisons can vary in their scale e.g. country, region or neighbourhood level and in how detailed they are e.g. comparing on a yearly, daily or every second basis. They also found some privacy concerns where detailed information about usage patterns became available to the public. Dodge, Metoyer & Riche (2010) encountered another issue where they found people believed fair comparisons would be difficult as different households have different appliances and different lifestyles.

In the interviews it was found that self comparisons were generally preferred to social comparisons as the participants thought it was more relevant. User 3 commented that "*In the app I can compare [my energy* *consumption] to neighbours, but I don't think it's very useful*". Similar to what Dodge et al. (2010) found the interviewees also pointed out that different people have different circumstances and possibilities.

Risks with feedback

While feedback can be a great tool there are also limitations and things that need to be taken into consideration in order for feedback not to be inefficient or have otherwise unintended or undesirable effects. Vassileva et al. (2013) investigated the effects of different feedback strategies on energy consumption. It was concluded that feedback risks only reaching and affecting the consumers interested in it. It was furthermore highlighted that the use of feedback on households with already low consumption can have the opposite effect and lead to the consumers using more electricity as they give less importance to it. Vasileva et al. (2013) concluded that information should be customised and that different feedback tools can be appropriate for different kinds of households. For low income households it is especially important to increase consumption awareness.

Similar to what Vasileva et al. (2013) concluded about feedback only reaching those interested in it, Suppers and Apperly (2014) stated that the techniques presented above; goal setting, providing information, rewards and penalties and comparisons were most effective for thoughtful users who reflect on what they do and why they do it and who are open to changing their behaviour if given a good enough reason. They also presented two other types of users who are less likely to benefit from detailed visualisations. Shortcut users want to have low energy consumption but do not bother thinking deeply about problems and what they can do to solve them. They want quick and simple solutions that require minimal decision making. The last category, pinball users, do not think of their decisions and they are unlikely to change their behaviour. Energy visualisation may not be suitable at all for these users and instead they may need more physical and forceful measures such as deleting or hiding features. However, people may find this too intrusive. Renström (2019) found that a majority of people want to be in control of the choices they make.

In a study done by Pierce, Fan, Lomas, Marcu, Paulos (2010) it was found that after participants received feedback on their energy consumption they spontaneously started describing their baseline consumption. The concept of a baseline consumption was however problematic in the sense that participants only focused on not exceeding their baseline and did not further challenge themselves by trying to lower the baseline.

5.3.4 Shifting consumption

Decreasing electricity consumption is not the only solution to the shortage issue, but shifting the consumption to other times of the day can be equally important (Kjeldskov et al., 2015). Domestic routines are often related to activities occurring during the same time of the day for a large part of the population, for example cooking dinner during the evening. When everyone performs electricity demanding activities simultaneously peak demand occurs, which leads to mainly two problems: insufficient infrastructure makes it challenging for electricity retailers to meet energy demand and it becomes increasingly difficult to rely on renewable, intermittent energy sources as peak demand always occurs at the same time. Expert 2 also spoke about these issues and stated that it is in the morning before work and in the evening, usually between 17:00-19:00, that most people use a lot of electricity, thus causing a larger strain on the electric grid. Large industries such as paper mills or data centres do use plenty of electricity, however they run around the clock thus not demanding a varying amount of energy contributing to peak demand. It was furthermore highlighted that it is not every evening that causes a capacity shortage, but approximately 10 hours per year, thus demanding an extension of the grid. Extending the electric grid would cause large expenses for DSO's. Capacity shortage is mostly an issue during cold winter afternoons. If a household uses large quantities of electricity during a summer night however, it is of less importance as there is an abundance of free capacity at such times. Expert 2 stated that only approximately 40-50 % of the capacity is used during the night.

The study conducted by Kjeldskov et al. (2015) found that the participants found it difficult to comprehend flexibility and the capacity-issue, instead they focused on saving money by decreasing the consumption. The participants furthermore focused on larger domestic appliances (e.g. laundry machines) that use a lot of electricity, but are not always a part of the daily routine. Moreover, it was found that participants felt discouraged as their behaviour did not have consequences as most people had fixed electricity prices. Participants in the studies conducted in this thesis project also argue that as most people are away from home during the day, the window of time to be able to do chores is limited, especially if they live in an apartment with regulations on when they are allowed to make noises. Furthermore, it was found that people feel unmotivated to change their electricity consuming behaviour if it has no effect on their electricity bill. User 3, for example, argued "*I don't really care about the electricity consumption, it's so little money per month anyway. It's like the same as my gym membership*", and User 4 said "*we don't exactly think about trying to change the electricity use, we use very little electricity anyway so it doesn't really matter*". Kjeldskov et al. (2015) furthermore found that some activities were perceived to be easier to shift to other times, for example doing laundry, as presence is not required. However, "luxury" activities like watching television, or activities with a "deadline", for example making breakfast for the children before school or daycare were considered impossible to shift to other times. Expert 2 had previously conducted research that showed that the average household can affect their peak consumption with 4-18 %, and stated that "*there is a limit to how much you can affect your consumption, you have to cook dinner for the family, but maybe you can wait to turn on your electricity driven sauna to another time*".

The simple solution to the capacity issue would be to enable people to shift their consumption to the night or other low-demand times. In the study conducted by Kjeldskov et al. (2015) the participants expressed a notion that DSO's and electricity retailers should be responsible to raise awareness about the peak demand issue among their customers. Expert 2 argued that an extensive introduction of power tariffs could be a solution to the capacity issue. This would create an economical incentive, which is supported by the finding that the price of electricity is the most common motivator (Kjeldskov et al., 2015). As Expert 2 stated, power tariffs would encourage consumers to run appliances successively instead of simultaneously and would thereby lower the grid strain as well as the cost for the household.

5.3.5 Measures

Consumers in general lack an understanding of their electricity consumption and what the possible effects of them trying to decrease their consumption might be (Suppers & Apperley, 2014). Furthermore, Vassileva et al. (2013) state that the connection between everyday behaviour and electricity consumption can be difficult to comprehend. The studies conducted in this thesis project support these findings. It was found that participants are unaware of what consumes energy in the home and how much, and that many consumers don't know what they can do to save electricity. User 3 explained that their electricity bill had been record high in February, even though they had a fixed price. They argued that this made no sense, that they had found no explanation and speculated during the interview "*I don't think I have changed my behaviour that much… Can it be the microwave? Or electrical cords? Do extension cords waste electricity?*". Furthermore, some participants believed they had already taken measures on decreasing their consumption, thus believing a further decrease would be almost impossible. This finding is supported by Pierce et al. (2010) who found that consumers who described themselves as "conservers" did not engage as much in the study they conducted, as they believed they already did everything they could.

In the study conducted in this thesis project it was found that participants were unwilling to make changes that would affect their quality of life. Some factors that were mentioned as factors inhibiting a decrease in consumption were children in the family, the amount of daylight and the outdoor temperature, basic activities (for example cooking or doing laundry) and wanting the home to give a cozy impression to by-passers and thus leaving the lights on for unnecessary periods of time. In the study conducted by Pierce et al. (2010) participants took measures such as turning lights off and shutting the computer off. Besides that, they expressed a resistance in making changes even if they were told that a certain behaviour used a lot of electricity, for example drying their clothes on a line instead of using the tumble dryer.

The majority of the respondents of the questionnaire stated that it's important to them to decrease their consumption, and 80% have taken some kind of measure to actively decrease their consumption. The most frequently occurring measure was to replace the heating system in their home to a more energy efficient one. Other common measures that the respondents had taken were to replace appliances for more efficient ones, to replace regular light bulbs with low-energy light bulbs, to turn off the lights when leaving a room, to lower the indoor temperature and to turn off other devices when they are done using it. It was desired to be able to compare the consumption of a period before a measure had been taken, and after, to be able to evaluate what the effect had actually been. User 4 expressed this as "*if we take some measures to decrease the electricity usage, like changing the windows to better isolated ones, it would be nice to be able to see if there is a difference compared to previous year*".

The second most frequent measure to decrease their consumption was to install solar panels. This is probably because the questionnaire survey was published in a group for solar panel owners, meaning across the average population this is probably not true. It should moreover be mentioned that the installation of a solar power facility does not decrease the actual consumption, but only decrease the need to purchase electricity from the grid.

5.3.6 Domestic solar power facilities

A common misconception is that it would be unprofitable to install solar panels in Sweden due to low rates of solar irradiations and few hours of daylight during the winters. However, Expert 1 explained that solar panels also produce electricity when it is cloudy, and during the winter the snow reflects the sun hence intensifying the irradiation. Furthermore, colder temperatures have a positive effect on the power production, as temperatures above 25 degrees decrease the efficiency. This explains how Sweden and Scandinavia still can get quite high efficiency despite fewer daylight hours during winter. Expert 1 furthermore argues that a clear day in March or September often allows for peak production as the temperature is not as high as in the summer. Moreover, Expert 1 stated that solar panels can still be efficient in northern parts of Sweden, especially considering the sun does not set during summer, even though not as efficient as further south.

Solar panels are often manufactured from non-renewable raw-material in China, as told by Expert 1. It was highlighted that the company was trying to find a different manufacturing process, but that it is a challenge. Furthermore, solar panels have a long life expectancy of 25-40 years but it is difficult to know for sure, as the technology is new. Expert 1 said that it is usually the inverter that is the first component to break, after approximately 15-20 years, but it can easily be exchanged for a new one. It takes approximately 1 year to "repay" the emissions caused by the manufacturing and transportation of the panels, whereafter the panels produce completely clean energy. Energimyndigheten (2018) explains that recycling of solar panels within the European Union, thus including Sweden, are encompassed by the WEEE-directive which regulates the recycling of electronic devices. The WEEE-directive advocates, among other things, that every solar panel retailer has a responsibility to educate the consumer on how to recycle the panels when they have been worn-out. In Sweden it is common that the panels are left for recycling at the recycling facilities run by the municipalities, as electronic disposal. The parts being recycled are the aluminium frames and the glass, but in the future when larger quantities of solar panels will have to be taken care of it is likely that a separate recycling facility for solar panels will also recycle the other metal waste as well.

Expert 1 explained what the prerequisites are to be able to install a solar power facility. An appropriate roof, preferably to the south and with an angle of 35-45 degrees, is optimal. Aiming the panels towards east or west gives a 20 % decrease in efficiency, it can however be beneficial as it produces electricity during a longer period of time in a day and not as much simultaneously. Furthermore, one should avoid shadow, as the panels produce up to 8 times less electricity when shadowed. The aspiring prosumer also has to contact the DSO to verify that the cables leading up to the house have large enough capacity. This can especially be a problem during a sunny summer day when the surplus production can get very large. Finally the prosumer has to choose an electricity retailer to sell their surplus to. When the facility has been installed, no maintenance is required. Expert 1 said that customers often ask if they have to shuffle snow or wipe away dust, but that it is not recommended as the glass can get invisible cracks affecting the effect negatively, if they are being interfered with.

There are mainly two different types of solar panels on the market: monocrystalline and polycrystalline. Monocrystalline solar panels reach an efficiency of 17-23 % and are black in colour. Polycrystallines are blue in colour and reach a slightly lower efficiency of 15-19 %, they are however cheaper (HemSol, 2021). Expert 1 stated the installations of polycrystalline have decreased immensely, as the price is not low enough to motivate the lower efficiency. Expert 1 also introduced a newly developed type of solar panel: semi-transparent double sided solar panels. They let the light through and collect it from the other side as well, leading to 20 % higher efficiency. Furthermore, they could be used for other purposes simultaneously, for example as a balcony rail or noise protection besides the railway through a town. Expert 1 believes there will be more similar innovative solutions in the future.

Taxes and regulations

When the solar power facility produces more than what is being used, the surplus is usually sold to an electricity retailer. Konsumenternas Energimarknadsbyrå (2020c) describes the subsidy and tax reductions available for prosumers. A household with solar panels can be liberated from paying VAT for the surplus, if the surplus does not exceed 30 000 SEK during one year. This liberation is often crucial for the facility to be profitable. Furthermore, a prosumer can also claim a tax reduction of 60 öre per kWh for micro production of renewable energy. This is done in the tax declaration, there are however limitations. A prosumer can only apply for a tax reduction for the surplus for maximum the same amount of energy they themself have used, but it can not exceed 30 000 kWh per year. In other words, of the solar power the facility produces, half shall be used by the household, and half can be transferred into the grid. Although the taxations and regulations don't prohibit people from installing more solar power than they consume, it might discourage them from installing more as they don't receive the same compensation for the surplus when it exceeds their annual consumption. Expert 1 stated that this can be problematic as some people choose to install less solar power than what might be possible, hence slowing the development and production. User 5 also talked about this, but had another perspective on the issue and argued that as a prosumer they don't regard overproduction problematic. They prioritised being able to help other households getting access to green energy prior to economical benefits and summarised it as "*I don't mind paying taxes if I can contribute and other households can use my solar power*".

The subsidy from the government in installation of solar panels has decreased each year between 2008-2016 as stated by Palm (2017). However, the price for solar panels has also decreased between the years, to almost a quarter of the initial price. Expert 1 stated that customers are price sensitive when deciding what producer to purchase a facility from, however a sense of security is also crucial. Moreover, it usually takes 10-14 years for the solar panels to be re-payed, sometimes quicker. In 2008 investment costs were the major barrier to installing solar panels (Palm, 2017). As the price has decreased the barrier also decreased, and the major barriers in 2016 were instead found to be issues related to administration, for example finding information about the market and signing deals with electricity companies to sell the surplus to. Expert 1 also spoke about this issue, and stated that "*people should not have to be an engineer or an economist to understand their facility. Like, ACDC, what is that? Usually, regular people have no clue how that works*''. It was furthermore stated that it should be more simple to install solar panels to not discourage potential prosumers.

Installation motives

Expert 1 has worked with solar panels since 2015 and described a development of the technology and the effect of the panels increasing from 300W to 420W per panel, but also a shift in the customers' purchase motives. Back in 2015 almost everyone installed solar panels out of ideological reasons, but an increasing number of customers highlight the economical benefits of producing their own solar power. Palm (2017) found that environmental motives were important both in 2008 and 2016, but that economic incentives had also become an important motive by 2016 hence all respondents in the later study had mentioned that the installation of solar panels were a financial investment. Expert 1 also stated that it's common that several people on the same street become prosumers, as they become aware of the possibility when a neighbour installs a facility.

The result from the questionnaire showed various motives for why people install solar cells, the result is shown in figure 5.10. In total, 40 people answering the questionnaire had domestic solar power facilities, and out of these a third mentioned environmental reasons and a third mentioned economical reasons for installing the facility in the first place. An interest in the technology of solar power was also a reason mentioned by a sixth of the respondents. The final sixth of the answers regarded EV's, for example to meet the increased consumption caused by the EV or to be able to charge the car at a low cost or almost free. Palm (2017) also stated that a difference in motive between 2008 and 2016 were that people in 2016 owned electric vehicles that they wished to charge with solar power. In the questionnaire survey it was found that out of the participants having solar panels, 65 % also have an EV.

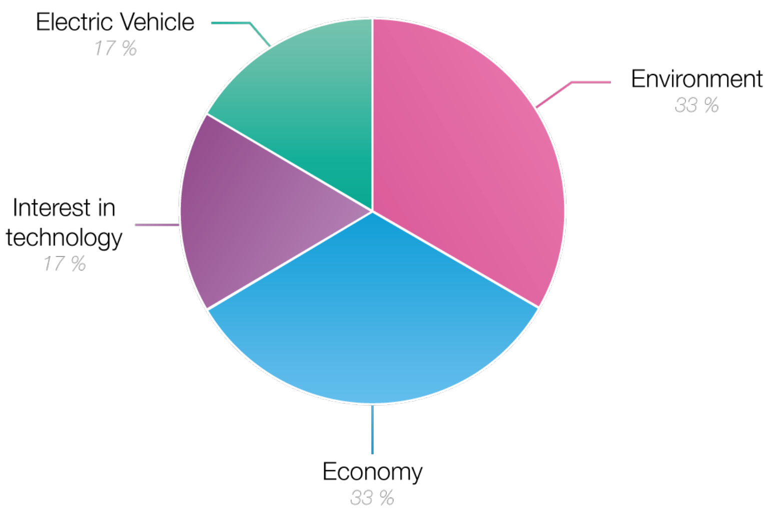


Figure 5.10. Reasons to install solar panels.

Social motives to install solar power were not mentioned by the respondents of the questionnaire. However, User 5 and User 7 both mentioned such motives when asked why they installed solar power. User 5 said that they had installed their facility after speaking with a neighbour working with solar panels and realising their house had the perfect conditions. User 7 installed their facility as they had realised they should practise what they preach, and to meet expectations following their profession, which involved sustainable living.

Overall, the attitude towards the domestic use of solar panels has changed from a futuristic technology only available to the early adopters, to something many people in Sweden can imagine themselves investing in. Palm (2017) refers to a study conducted in 2016 that found that 73% of people in Sweden wished to install solar panels on their house. Furthermore, Palm (2017) found that people in the age group 45-65 are most likely to install solar panels. They are also more aware and have a more positive attitude on solar panels. Expert 1 stated that overall there has been an immense increase in the amount of people installing facilities, an increase Expert 1 believes will continue exponentially. It was highlighted that there is a plenitude of houses all over Sweden that have great potential for solar power.

5.7.3 Electric vehicles

Out of the people answering the questionnaire, 58 people own an EV. The result from the questionnaire showed that there are several different reasons as to why people get an EV, the result is shown in figure 5.11. The most common motivator, mentioned by 40 % of the respondents of the questionnaire, was the environment. Out of these people, many mentioned the climate and that they would like to reduce their use of fossil fuels. The next most prevalent motivator was economic reasons which was mentioned by 36 % of the respondents. This might sound counterintuitive as EV's are generally sold at a higher price than petrol cars, but as discussed above in section *5.3.2 Socio-demographic factors*, the operation cost is lower for EV's (Augustsson, 2020). This coincides well with the beliefs held by the people who answered economy as their motivation, as many of them further explained that the use of electricity as fuel is cheaper than petrol and that the service cost is lower. In the interview, User 6 who owns an EV also talked about this. User 6 said that EV's are considerably cheaper to drive and that they require less service, as there is no oil or similar that needs to be changed regularly and stated that *"I save 50 000 sek per year by refueling with electricity instead of fossil fuel"*. User 6 concluded that an EV is advantageous when driving a lot.

There was also 10 % who got an EV because of interest in technology and 6 % who were simply curious about new and trendy things. Furthermore there were 6 % who stated that the user experience of using an EV was better than that of a petrol car. They argued that it is convenient to charge at home instead of driving to a service station, that it is more pleasant to drive, that an EV is better suited for short distances and that an EV has better operational safety. Lastly there were some who said that a reason they got an EV was because they have solar panels. In particular, all of these people said that on a yearly basis they produce more than they consume so purchasing an EV was a way to utilise the surplus production. Of the respondents owning an EV, 43 % also have solar panels. As discussed above in section *5.3.6 Domestic solar power facilities,* a too large surplus production on a yearly basis is less profitable because of taxations and regulations. This could be a contributing factor to why they would prefer to use their surplus production rather than selling it.

Some respondents answered that they leased a car or used a company car. Being able to use a company car for private use is a type of employee benefit (Skatteverket, n.d.a.). For the employer there are governmental incentives to provide cars fueled by electricity or other environmentally friendly fuel (Skatteverket, n.d.b.).

When asked why they would like an EV there were also quite a large number of people, 9 % of them, who spontaneously mentioned that owning an EV is in fashion or that EV's are the future. Looking at statistics it is true that the market for EV's and Electric Hybrid Vehicles [EHV] is growing (Österberg, 2020). In 2020 the share of chargeable alternatives in Sweden had increased to 29 % compared to 11 % in 2019, although the increasing trend was expected to slow down in 2021 due to less favourable incentives from the government.

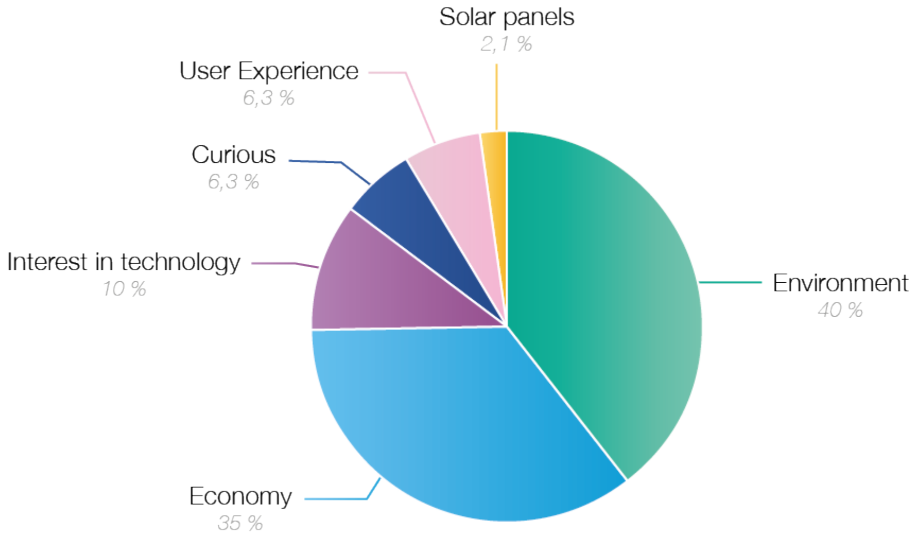


Figure 5.11. Reasons to purchase an EV.

EV charging and strain on the electric grid

According to Wang et al. (2021) there are also other issues regarding a fast growing EV adoption that could either hinder its growth or cause problems for the electric grid. There are pressing concerns from the electricity sector regarding the strain EVs put on the electric grid, as EV charging can cause sudden spikes in power demand. Large-scale EV deployment requires careful electricity sector planning so that the long-term demand for electricity can be met without compromising economic viability or grid stability. Wang et al. (2021) concludes that cities should exercise caution in short-term, large-scale EV deployment. According to a study done in Sweden the current electric grid could manage that 42 % of the cars in a district are chargeable without the transformer needing to be replaced (Nohrstedt, 2019). However, there would be problems if everyone were to charge their cars in the evening. There would be a lack of power capacity which would happen primarily at district level. The study showed that the maximum power in a district increases significantly as the number of EV's increases, largely because EV charging usually occurs when society's other power output is the highest.

This however contradicts the findings from this thesis. The result from the questionnaire showed that two thirds of the respondents owning an EV and no solar panels charged their EV's during the night. Others charged when it was most convenient, for example at work or when they got home from work. Out of the people who provided an explanation to why they prefer charging during the night a majority of 53 % mentioned wanting to put less strain on the electric grid as either the main reason or as a contributing reason. Other common reasons were that electricity is cheaper during the night or that it is more convenient. For the people owning both EV and solar panels 62 % charged during the night and 25 % charged either during the night or during the day with solar power depending on the circumstances. Many used solar power when the production was high, for example charging with solar power during the summer and at night during the winter. Most people were able to remotely control or schedule the charging either through a wall-box charger or an app. User 6 was one of those who could not do it but commented *"I would like to be able to schedule the charging to when the cost is the lowest"*.

It can be concluded that being able to schedule charging to times where strain on the grid is low, cost is low, or when the production is high are desirable functions that are beneficial for both users and the electric grid.

5.4 Personas

Based on the findings presented in section 5.3, four personas were developed to support further ideation, concept development and later on also serve as a basis of evaluation.

CHRISTER & AGNETA

Christer and Agneta are both eager to read new research and closely follow the political discussion on sustainable development, and it's a common topic of discussion at the dinner table. Christer and Agneta recently installed solar cells on their house, which meant that they are able to be part of the environmental discussion. Producing their own solar power also ensures that their electric vehicle is charged with clean energy and that they are doing their part in easing the strain on the electric grid. It's important to them to avoid peak demand and therefore try to use as much of their own electricity as possible. They both feel a strong sense of responsibility for the environment; they want the new generation to grow up in a sustainable world.

Christer and Agneta have a log in to a website to follow the production from the solar cells and a mobile application to control the charging of the EV. They also follow their current consumption on a smart meter in the hallway and compile the information in an Excel sheet to track trends and statistics. This is time consuming but worth it since it gives a sense of control and an understanding of how to improve. Christer and Agneta appreciate a lot of information and statistics, and to be able to compare previous months to track improvements and get feedback.

Age: 59 & 62

Occupation: Agneta is a Business Developer and Christer is a surgeon

Family: Married, older kids that have moved out

Housing: Detached house in a small town

"We have always felt responsible to help where we can"

"To live sustainable comes naturally. We are worried about climate change for our kids sake…"

Photo by Esther Ann on unsplash.com

LINN

Linn is enjoying her life at University to the fullest. Her schedule is often crammed with nights out with friends, engagement in the student union and of course studying. She doesn't spend very much time in her apartment, and when she leaves home she always turns the lights off since she has heard that is important. Other than that, Linn doesn't really care about electricity consumption, she uses the appliances she needs without thinking further about it. When the bill arrives she pays it, it is so low anyway so bothering to try to lower it is not anything she does.

Linn and her friends often talk about how horrible climate change is, but she doesn't do anything to help it either since she hasn't bothered to look into how she can contribute. Linn would benefit from easy access information about action and their consequences on both the environment and the bill. She thinks the invoice is boring and doesn't always read all the information available. Linn would appreciate a mobile solution making the information accessible and visually fun to look at to increase motivation.

Motivation to decrease consumption

Awareness of consumption

Age: 22

Occupation: Student

Family: Living alone

Housing: Small rental apartment in the city

"I don't really care about the consumption since it's so little money per month anyway"

"I am scared of climate change but I haven't bothered trying to get enough knowledge about it"

Photo by Noémi Macavei-Katócz on unsplash.com

NIKLAS

Niklas is living a stressful life taking care of his two small kids alone. He enjoys it and they are his whole world, but he is also exhausted once he has put them to sleep. He barely has time for himself anymore, and keeping track of his electricity consumption is his last priority right now. Although he often wishes he could find a way to save more money, he just doesn't have time to bother. Once the invoice arrives, he pays it but doesn't reflect very much about it.

He has a log in to a website of his electricity supplier, but he finds the graphs confusing as they don't tell him if his result is good or bad. To be able to see this in another way would be appreciated! Niklas also wishes some things would just adjust automatically without him having to reflect… However, it's important that he can override automations as life with kids can be unpredictable.

Motivation to decrease consumption

Awareness of consumption

Age: 38

Occupation: Dental hygienist, but are currently on parental leave

Family: Single-parent with 2 kids (1 and 4 years old)

Housing: Semi-detached house in the suburbs

"I find it difficult to affect my energy consumption with kids in the house…"

"The invoice is kind of complicated with a lot of different numbers, taxes and charges"

Photo by Nathan Dumlao on unsplash.com

Motivation to decrease consumption

Awareness of consumption

BENGT

Bengt and his wife installed solar panels a few years with the vision of being able to get cheap electricity and maybe even earning a bit of money on it in the long run. They also hoped for the house to gain a value increase. Since Bengt's wife passed away, it has become increasingly important for him to lower his cost of living as he lives alone in a large house. Every morning Bengt checks the weather forecast on the television and the expected price variations of electricity throughout the day on a website. He usually tries to avoid using the electricity he produces during the day, since it's economically beneficial to sell the surplus production and buy electricity from the grid during the night.

Bengt spends a lot of time creating budgets and plans for how to increase the gain from the solar panels. However, he thinks the taxes and contracts with electricity companies are complicated. It was easier back in the days when you didn't have to choose everything yourself! Bengt would appreciate advice on how to decrease consumption and save money, as well as some automatic functions making decisions for him, to steer consumption to more economically beneficial times of the day.

Age: 69
Occupation: Retired
Family: Living alone with 2 cats
Housing: Detached house in the country side

"We installed solar cells to be able to get cheap electricity, hopefully it will be almost free in a few years!"

"I adjust my energy consumption to times of the day when it's cheaper"

Photo by Ashkan Forouzani on unsplash.com

5.5 Summary

The most prominent findings presented in this chapter, have in this section been summarised. The conclusions presented here will be brought forward to the next phases and will be important for the continuous work.

Information format

It was found that people having an app are more aware of their consumption. People owning both EV and solar panels are much more aware of their consumption and they also have an app to a much larger extent than those having neither.

Socio-demographic factors

Low income households value their economy as a slightly more important reason when it comes to saving energy than high income households who value the environment as slightly more important. High income households are more likely to get an EV, however, income does not affect the likelihood of owning solar panels to the same extent. Households in detached houses without children are more aware of their consumption and can affect it more than those in detached houses with children. Households in tenant-owned apartments are to a larger extent aware of their monthly energy consumption, compared to those in rental apartments. However, households in detached houses are more aware of their consumption than those living in apartments, they can affect their consumption to a larger extent, it is more important to them to decrease their consumption and they also use more electricity. The economy and environment are equally important to detached house owners while the economy is more important for those living in an apartment.

Feedback

There are different types of feedback and different techniques to encourage energy saving behaviour. Direct feedback is more effective than indirect feedback. Providing tips and information is useful for users who feel they lack knowledge or do not know what to do. Goal-setting is one of the most effective strategies in increasing energy saving behaviour. Rewards and penalties can be used to encourage or discourage certain behaviour. Furthermore, comparisons can be used to motivate people and to set a reference point. Self comparisons are generally preferred to social comparisons. Feedback is most effective for people interested in it.

Shifting consumption

Peak demand occurs when a large part of the population do energy consuming activities at the same time, usually in the morning or in the evening. Peak demand makes it difficult to meet the energy demand and to rely on renewable intermittent energy sources. Problems are that consumers find it difficult to shift their consumption if they are home only a few hours each day and they are unmotivated to shift their consumption if it does not affect their electricity bill. Luxury activities or activities with a deadline were considered impossible to shift to other times. Tariffs would create an economic incentive

Measures

Consumers have a difficult time comprehending their behaviour and electricity consumption. They find it difficult to know what measures have an effect and to know what to do. They find it unmotivating to save electricity if it does not affect their economy. Furthermore, they did not want to take measures that would affect their quality of life. The majority of participants had taken some measures to decrease their consumption whereof the most frequent one was changing the heating system.

Installation of solar power

Incentives to install solar power have shifted from environmental to also include economical reasons in just a few years. Subsidies from the government to install solar panels have continuously decreased during later years but prices have also decreased.

Electric vehicles

The most common motivator to get an EV was the environment, second one was economy. It would create capacity shortage problems in the cities if everyone gets an EV and wants to charge at the same time.

6

IDEATION

This chapter will present the aim, procedure and results from the *ideation phase*, which were conducted in parallel with the *exploration phase*. The ideation consisted of an initial ideation developing general ideas and a symbol-ideation.

6.1 Aim

The aim of the ideation phase was to iteratively ideate ideas to be able to evaluate with users continuously. This would ensure the work taking a direction supported by the users.

6.2 Procedure

The methods used in the ideation phase were several ideation-methods to explore and create new ideas, as well as interviews and a symbol-survey. The implementation of these methods will be presented in the following sections.

6.2.1 Ideation sessions

Two ideation sessions were conducted. The initial ideation focused on creating ideas that would be used as mediating tools to facilitate discussion during the interviews held with users. This was believed to aid the users express what they would like to have in an energy visualisation app if they had no experience with one before. The second ideation presented in this section is a symbol ideation session. This was conducted further on and resulted in a number of alternative symbols to be evaluated with users.

During the initial ideation session, a combination of brainstorming and braindrawing was done. One theme was focused on at a time, for example how to visualise strain on the grid, flow of electricity in the household and production from solar panels. The themes were based on the functions found during the market analysis. For each theme there was first time to individually come up with ideas and then a presentation and discussion of the ideas followed where more ideas were created or old ideas were revised or combined. There was no set time limit and instead the discussion started when it was difficult to individually come up with new ideas. Sometimes themes which had already been ideated around were revisited if new ideas came up. The ideas were drawn by hand on paper with ink pens and colour pens. Some ideas were further described with text.

For the EV theme, which had many different functions often closely linked together, a morphological matrix was done. This was in order to get an overview of the different options of the functions and to be able to see which options would work well together. Functions included were for example how to visualise the charging, how to visualise that the EV is currently charging and how to schedule the charging.

There was a discussion of which ideas were most promising for each theme and two to four ideas for each theme were chosen to be shown during the interviews. These were remade digitally in *Adobe Illustrator* in order to make them look closer to what they would in an actual app, and also to make them have a more cohesive style.

A separate ideation session was done for the symbols. It was done in the same way as the initial ideation, with a combination of brainstorming and braindrawing, although generally a bit quicker and with less colour and describing texts. One symbol was ideated around at a time, for example wind power, hydro power and nuclear power. Four to six options for each symbol were chosen to be digitally developed in *Adobe Illustrator* and later further evaluated with users.

6.2.2 User evaluation

To evaluate the ideas developed during initial ideation the users participating in the interviews presented in *5.2.4 User interviews*, were also shown the ideas that had emerged from the ideation session. The participants are presented in table 5.1. This was the second part of the interviews. The participants were shown different ideas of visualising different functions through a PowerPoint. Conducting the interviews remotely enable screen sharing which made it possible for the participants to see the PowerPoint.

Images describing the same function were grouped together on the same slide. For each slide the participants were asked a number of questions. The questions were adapted to each slide but for the most part the same questions were asked, namely if they could guess what the different images mean, what they think about the images, which one they think is the most clear and easy to understand and if they have any suggestions on their own. The purpose was to create a discussion and to collectively find strengths and shortcomings of the different types of visualisations and to find improvement opportunities and alternative ways of doing it. The attributes included in this part of the interviews were as follows:

- Consumption and strain on the grid, horizontal version
- Consumption and strain on the grid, circular version
- Comparison between the linear and circular version
- Flow of electricity
- Electricity consumption integrated with solar power production
- Production from solar panels
- Integrating of EV charging in the consumption diagrams
- Visualisation of the environmental effects

6.2.3 Symbol survey

In order to get feedback on symbols and choice of colours, a symbol survey was conducted. As a focused target group was not considered necessary, the survey was shared among peers at Chalmers University of Technology and among friends and family. The symbol survey received 53 answers. The survey consisted of two parts, whereas the first regarded symbols and the second regarded colours. The respondents were presented with 4-6 variations of symbols for each attribute, and asked to pick the one they perceived to be representative for the attribute in question. They were furthermore asked to share feedback or if they had any other ideas in a separate question with a free-text option. The attributes were as follows:

- Good economical choice
- Good environmental choice
- Wind power

- Hydro power
- Solar power
- Bio energy
- Nuclear power
- Electric vehicle
- Power grid
- Achievements
- Charging

For the second part of the survey, the respondents were first presented with 14 colours, each assigned a letter. They were thereafter asked to choose what colour they perceived to represent each of the following attributes:

- Neutral/inactive
- Chosen/inactive
- Electricity consumption
- Solar panels
- Environmental sustainability
- Electric vehicle

The respondents were furthermore asked to explain their choice, this was however not a requirement but contributed to the analysis.

6.3 Result from the first ideation

The result from the initial ideation was illustrated using Adobe Illustrator and shown to the users participating in the interviews also discussed chapter *5 Exploration*. The ideas were evaluated by the users and used as mediating tools to facilitate discussion on the interviewees preferences. This enabled an opportunity to discuss solutions in an early stage of the project.

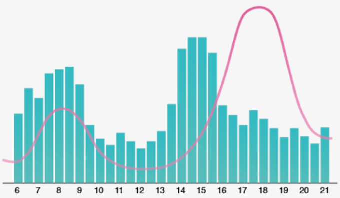


Figure 6.1a. Strain on the grid: horizontal version 1.

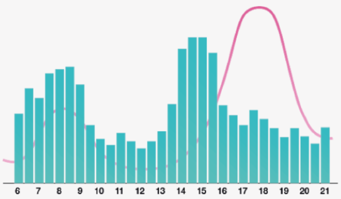


Figure 6.1b. Strain on the grid: horizontal version 2.

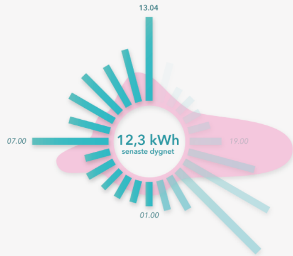


Figure 6.2a. Strain on the grid: circular version 1.

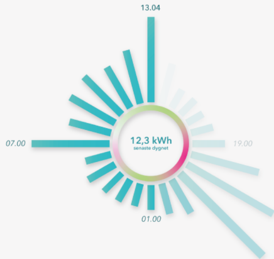


Figure 6.2b. Strain on the grid: circular version 2.

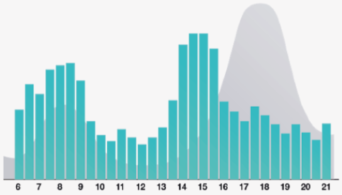


Figure 6.1c. Strain on the grid: horizontal version 3.

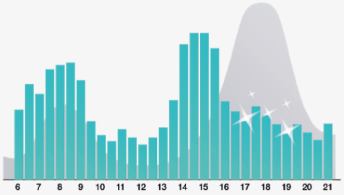


Figure 6.1d. Strain on the grid: horizontal version 4.

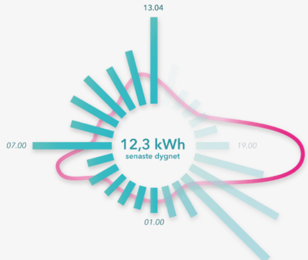


Figure 6.2c. Strain on the grid: circular version 3.

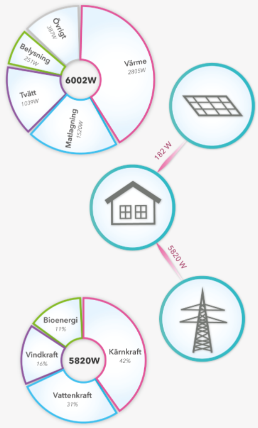


Figure 6.3a. Flow of electricity 1.

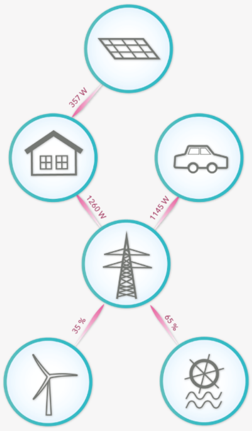


Figure 6.3b. Flow of electricity 2.

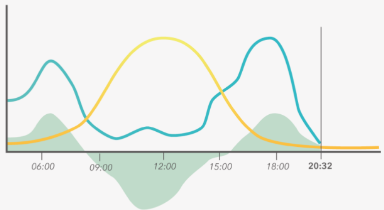


Figure 6.4a. Solar power: production and consumption 1

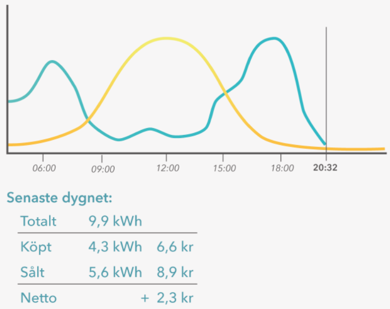


Figure 6.4b. Solar power: production and consumption 2

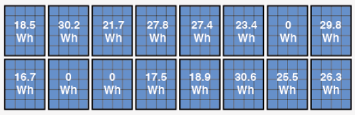


Figure 6.5a. Solar power: solar panels 1

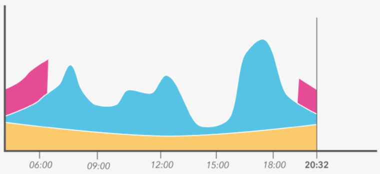


Figure 6.6a. Consumption with EV 1.

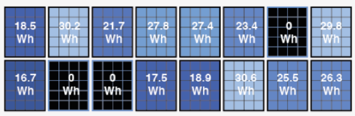


Figure 6.5b. Solar power: solar panels 2

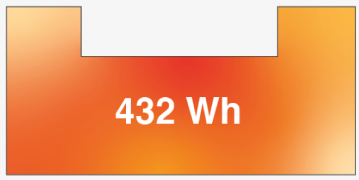


Figure 6.5c. Solar power: solar panels 3

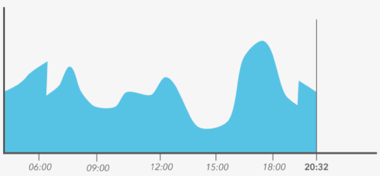


Figure 6.6b. Consumption with EV 2.

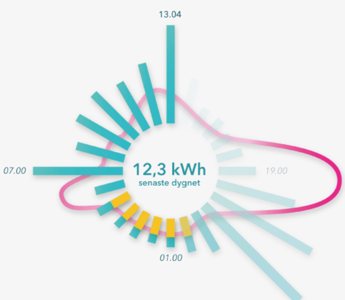


Figure 6.6c. Consumption with EV 3.


Figure 6.7a. Visualise improvements 1.

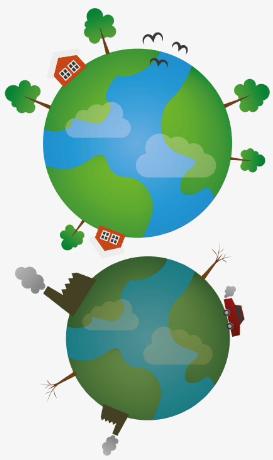


Figure 6.7b. Visualise improvements 2.


Figure 6.7c. Visualise improvements 3.

6.3.1 Strain on the electric grid: horizontal version

In order to show the household consumption and the nationwide strain on the electric grid in the same diagram, four different versions were developed, which can be seen in figure 6.1a-d. They all provide the same information but in different ways. The intention behind these ideas were to visualise when the strain on the grid is high, how it corresponds to the user's own consumption and to motivate the user to shift their consumption to other times when the strain is lower. The green bars represent consumption while the pink lines in figures 6.1a-b and grey areas in figures 6.1c-d represent strain on the grid. The x-axis shows the time of the day and the y-axis, although not explicitly shown, shows energy. It was discussed if the measurement for strain on the grid should also be put on the y-axis or if it should have its own axis. Furthermore it was discussed what units to use with percentage of maximum grid capacity being the strongest option. These questions had not been decided at the point of the interview. The different versions differ in whether they visualise strain on the grid as a line or an area, if it is behind or in front of the consumption bars and whether or not they have any positive feedback when consumption is low and the grid strain is high as in figure 6.1d.

When the interviewees were asked to guess freely what the diagrams represent most of them correctly guessed that it had something to do with their energy consumption over different hours of the day. Most users correctly guessed that the blue-green bars represented consumption but were unsure about the pink line and the grey area. However, when told that they represented strain on the grid they thought it was logical.

Generally the interviewees found the format of the diagrams to be easy to understand and conveyed that it corresponds well with how they usually receive this type of information. One interviewee saw similar diagrams at work every day and another one compared it to the diagrams used on the stock market. There were also positive comments about the usage of two different chart types in the same graph since it was believed to increase the accessibility. It was further pointed out that relying solely on colour to differentiate between them could make it difficult for people with visual impairments. Some drawbacks mentioned for the horizontal versions were that they were somewhat boring and that they would not fit well on a mobile screen. It was also suggested that information the user cannot control, such as the strain on the grid, should be in a neutral colour.

When comparing the four different diagrams, participants expressed that if the line was behind the bars as in figure 6.1b it appeared to be hidden and difficult to see. In the grey, filled versions (figure 6.1c-d) it was easier to see as the grey parts could be seen through the gaps between the bars. Figure 6.1a was believed to be the clearest. Positive feedback like the sparkles in figure 6.1d were appreciated as it makes obvious that one is doing something good.

New ideas that emerged were for example that there could be another colour for the bar "right now", that the previous days' bars could be seen in the background and that the bar for the current hour is filled up gradually until a new hour starts. It was also discussed that it would be beneficial to be able to see a forecast on strain on the grid and lastly that the potential economic gain from avoiding using energy when strain on the grid is high should be visualised.

6.3.2 Strain on the electric grid: circular version

A circular version of the consumption in combination with the strain on the grid was developed in three different versions. The consumption is visualised in bars placed around a 24-hour clock in all three versions, with the strain on the grid visualised in three different ways. The current time of the day will always be placed upwards, meaning the bars will move counter-clockwise when a new hour is entered. The past hours are placed around the circle, with the bars symbolising the times furthest away from current time faded to highlight that they are the most distant in time. In figure 6.2a the strain is visualised as a filled area, with high strain shown as the filled area being large and far from the middle (e.g. at 19:00 in the figure). The version shown in figure 6.2c is intended to work in a similar way, but the strain is shown as a line varying in saturation instead. In the version in figure 6.2b the strain is instead shown as an inner circle varying in colour between green and pink. The green is showing the user when the strain is lower, and the pink when it is higher.

When the interviewees were shown the circular versions of how to visualise strain on the electric grid in combination with consumption they all correctly guessed what the different attributes symbolised, which is partly believed to be because they had previously viewed the horizontal versions. Comments from the interviewees regarding the circular version were for example that they appreciated viewing current consumption and that they thought it was appropriate to put the time around a circle to resemble an analog clock. Which one was thought to be the most accessible varied between interviewees, but figure 6.2b and 6.2c were mentioned most. It was stated that since the pink line or area also will rotate, figure 6.2b might be better. However, others highlighted that the form of the versions in figures 6.2a and 6.2c will in a more direct way show the strain on the grid than the colour of the inner circle in figure 6.2b. On the other hand it was also stated that green colour is strongly associated with doing good, and red with doing wrong. The participants furthermore mentioned resemblance with a parking application, screen time and bedtime in iPhone when shown the circular version.

New ideas emerging regarding the circular version were for example that figure 6.2a and 6.2c also could vary in colour like figure 6.2b and that the previous day would also be included but less visible. Furthermore it was discussed that an option to switch between the circular and horizontal view would be appreciated.

When asked to compare the horizontal version and the circular version it was clear that the predominant favourite was the circular version. The participants stated that the circular version was more fun and original, and also that it was more suited for a mobile screen compared to the horizontal one. However, they believed it would take longer to understand the circular version, as most people are used to seeing horizontal bar charts in everyday life. Finally it was stated by several participants that it would be interesting to view the strain on the grid, and that it would trigger reflection before using appliances.

6.3.3 Flow of electricity

In order to show the flow of electricity two different versions were developed which can be seen in figure 6.3a-b. The direction of the flow is visualised by the pink arrows and the size of the flow is written in text next to the arrows. The symbols in the rings represent solar panels, the household, an EV and the electric grid. In this example the household gets energy from both solar panels and the electric grid and the EV is also charged with electricity from the grid. If the user does not have solar panels or an EV these would not be included. In figure 6.3b there are also symbols for wind power and hydro power, showing that the electric grid for the moment uses those sources. In figure 6.3a this has instead been visualised in a pie chart showing the distribution of different energy sources. This pie chart will appear if the user clicks on the electric grid. Similarly, the user can get information about distribution of how the energy is consumed in the household by clicking on the house symbol. In the middle of the pie chart the user can also read how much is momentarily consumed in the household, in this case 6002 W.

When the interviewees were shown the illustrations of how the flow of electricity could be visualised, they all understood what they were supposed to show. The directions of the flow symbolised by the arrows between the circles were also straightforward for all. The two different versions of the flow of electricity is shown in figure 6.3a and 6.3b, with the major difference being the division of energy sources.

Some participants perceived figure 6.3b as more of a flow compared to figure 6.3a. However, others thought that figure 6.3b was cluttered, especially if more components were added to the energy mix. Furthermore, the pie charts in 6.3a were perceived to be pedagogical, especially if they were to replace the circle symbolising the grid and house respectively. It was also appreciated to be able to decide for oneself how much information to display by clicking the circles. To increase awareness of energy sources was also appreciated by the participants, as they did not want to use electricity if it was produced from a non-renewable source. Separating the EV from the rest of the household felt logical to the participant driving an EV, as it consumes a large amount of electricity and could otherwise make the total consumption of the house misleading. Finally, it was highlighted by all participants that it is crucial that the flow and pie charts are individual and not some average distribution withdrawn from other data as that would decrease the trust of the solution.

An abundance of new ideas emerged regarding the flow of electricity in the home. Some new ideas about the arrows were that the thickness of the arrow could visualise how big the flow of energy is and that the colour of the arrows could show if it is production or consumption, for example green from the solar panels. Some ideas about the circles were that bigger circles could symbolise a larger share of energy, that there could be less strong colours for wind and hydro power and that wind and hydro power would not be visible all the time but appear when the grid symbol is clicked on. Furthermore it was suggested that clicking on the solar panel symbol could give more information about them, that if the EV is not charging the arrow could disappear but the circle is left as a shortcut to EV information and lastly that the numbers beside the arrows could move into the circles instead. Ideas regarding the pie charts were that there could be a pie chart for the distribution in the household for the version in 6.3b too and that the pie charts could be closed when clicking on them. Some participants suggested that the total consumption including both the house and the car as well as a summary of the day should be visible somewhere. Another idea was that if the grid energy consisted of for example an unusually high degree of wind or hydro power the app could provide information about why. Similarly, an idea was that if the electric grid sources changed and there were a large import of for example coal power the user could get a warning. Lastly, an idea was that information about strain on the grid and shift in consumption could be included here.

6.3.4 Solar power: production and consumption

Two different concepts, which can be seen in figure 6.4a and 6.4b, were developed with the intention to visualise both energy consumption and production from solar panels in the same diagram. The purpose of having them in the same diagram was for the user to easily be able to see the net value and how the production and consumption compare against each other over the day so that the user would be able to deduce, for instance, how much of the energy production is utilised in the home and how much is sold at specific times. In both diagrams the yellow line visualises the production while the blue line visualises the consumption. The x-axis shows the time and the y-axis is supposed to show energy. The black vertical line to the right shows the current time. The difference between the two versions was that in figure 6.4a the green areas show the net value of production and consumption, with the area below the x-axis symbolising a surplus of energy which is sold. In figure 6.4b there is instead an information table with information about how much energy is bought and sold as well as the total value over the day. It also shows the cost or profit from this.

When the interviewees were shown the diagrams in figure 6.4a-b they all correctly guessed that the yellow line visualised the production from solar panels and that the blue line visualised the consumption. The green area in figure 6.4a was initially found to be less clear but obvious when explained. Some of the interviewees liked the green area while some did not. The ones who liked it believe it made it easier to see how much was bought and sold while others argued it was unnecessary and especially redundant if the information table in figure 6.4b would be present as well. Regarding the information table there were some who believed it may be redundant to have on the start screen and that it might be better to see the information after scrolling down or after clicking on the lines in the diagram. The information they would be interested in seeing would be bought, sold and net energy. A new idea that came up was to combine figures 6.4a and 6.4b so that the user can see both the green area and the information table. Another idea was that the text in the information table could have the same colour as the corresponding graph.

6.3.5 Solar power: solar panels

In order to show how production from individual solar panels can be visualised two versions were developed which can be seen in figures 6.5a and 6.5b. In both 6.5a and 6.5b the production over the latest hour is written on each solar panel. In figure 6.5b variations in how much energy has been produced are shown by using different colours, from light to dark, where light blue colours mean more energy, darker blue colour means less energy and black means no production at all. Blue colours were used since the physical solar panels can have a blue tone. In addition a third version which can be seen in figure 6.5c was developed which does not show individual solar panels but instead the total production as well as variations in energy produced over the area where the solar panels are placed. Contrary to the colour theme used in figure 6.5b, warmer yellow and red colours are used in order to stronger connect to the colour of the sun and solar intensity.

When the interviewees were shown the illustrations of individual solar panels they found it obvious what they were visualising. They all preferred 6.5b to 6.5a since they looked at the colours first and it gave them a good overview. However, all of them interpreted the darker colours as the panels receiving more sun and the lighter colours as less sun, which was the reverse to the intended meaning. All of them correctly guessed that black panels meant no sun at all. The interviewees generally believed it would not be necessary to see the production from individual panels everyday but that it would still be good to have the possibility in order to check that everything functions as intended or in order to optimise the production. It would otherwise be enough to see a less detailed view of the whole roof as in figure 6.5c.

Some new ideas that emerged were that warm colours could be used instead of cold colours for the solar panels as warm colours are more associated with the sun, or that the user could choose the color theme oneself. Furthermore it was discussed that instead of showing the power of the individual solar panels it would be better to show the percentage of the whole production each solar panel contributes with. Lastly there was an idea that the individual solar panels could be reached through clicking on figure 6.5c.

6.3.6 Consumption with EV

In order to show EV consumption together with the household's other consumption two different versions were developed which can be seen in figure 6.6a and 6.6c. In the version shown in figure 6.6a the energy used for heating the house was also included. The pink areas visualise the consumption used for EV charging, the yellow visualise the heating and the blue visualise the remaining consumption. Figure 6.6b shows how the diagram would look if different kinds of consumption were not colour coded. Figure 6.6c is the same as 6.2c showing the consumption and the strain on the electric grid, except for that this version also includes what part of the consumption is used for the EV, which can be seen in the yellow bars. The meaning of the colours are unfortunately not consistent between 6.6a and 6.6c, but the interviewees were informed about this beforehand.

The participants were not able to guess what the different diagrams meant without context and suggested that explaining text would help. Being able to see the division of different kinds of consumption was an appreciated feature. It was said to be interesting and making it easier to see what actions or functions affect the consumption the most. The version seen in 6.6c was thought to be the easiest to understand.

6.3.7 Visualise improvements

To visualise the effect of a changed behaviour on the environment for the user, three different versions were developed, which are shown in figures 6.7a-c. The idea was to facilitate for the user to understand, in an intuitive way, that how they use electricity actually does impact the environment. When the user has increased their energy consumption compared to the previous period of comparison without it having a natural explanation (e.g. more people in the household or purchase of an EV), the figures in the lower row will be displayed, and when the consumption has been decreased the figure in the upper row will be displayed. Exactly where, when and how this would be used in the solution had not been decided upon beforehand.

Overall, the participants were positive to get feedback in a visual way compared to only reading numbers and bars, and it was stated that it is a good way to quickly comprehend the consumption. There were however varying opinions on when and where to include such feedback; some wanted it to be the first thing when entering the app and some others would prefer to include it in a weekly or monthly report. It was furthermore highlighted by participants that the negative feedback should not be too negative, and that positive encouragement is preferred and believed to have a greater impact. Some participants also said that it would be like a fun game, that they would feel like they would be encouraged to take care of the earth, polar bear or tree. It was also stated that this could be a good way to involve children and get them to understand the effect of excessive electricity usage.

When shown the three ideas, all participants immediately commented on the polar bear in figure 6.7a. It was stated that seeing the polar bear shift from being happy to miserable provokes feelings of empathy and a guilty conscience. It was also interpreted as playful and participants stated that it was obvious that it was symbolic and not literal, which was positive. Furthermore several participants commented that the circle around the polar bear relates back to the circles present in many of the previous ideas, and that it would be a consistent design theme throughout the solution.

The idea visualised in 6.7b shows a happy and prosperous earth, which would be exchanged for a dull and emission-filled earth if the consumption would increase. This version was the participants' least favourite one. It was stated that industries and cars must be allowed to exist and that it could be interpreted as economic growth and thereby something positive by some. Furthermore it was highlighted that cars that emit carbon dioxide would be irrelevant if the user has an EV. However, they agreed that everyone wants a happy and green earth but that the version overall does not radiate playfulness but just misery, which could make the user discouraged.

Comments regarding the tree in figure 6.7c differed. Some participants stated that the tree was their preferred version, and that it was interpreted as positive when the tree started to grow flowers. However, one does not get a guilty conscience to the same extent when the tree is flagging compared to when the polar bear gets sad. Furthermore it was stated that it could be interpreted as the shifting of seasons instead of the tree dying, and that autumn is not necessarily something negative.

One idea that emerged during the discussions was that it could be displayed in combination with how much CO_2 has been emitted. It was mentioned that it would be appreciated if the environmental consequences or savings were adjusted to what the user, for example if the user has an EV, the savings could be displayed as how far they could travel in their car. Other ideas on visualisation of the consequences were that a footprint could be used as it is an established and recognised measure of environmental influence, that snow could fall on the polar bear if the improvements are large and that a sound signal could be used to further highlight improvements or worsenings.

6.4 Result from the symbol survey

The symbol survey consisted of both symbols and colours. The result consisted of both statistical data of how the votes were distributed over different options and comments providing further understanding of why they made certain choices, their opinions on certain options as well as new ideas.

6.4.1 Symbols

In this section, the evaluated symbols will be presented, as well as the result and the final version of each symbol.

Good economical choice

The symbol for a good economical choice is thought to be used when the user wants to optimise for example charging of the electric vehicle to times of the day when the electricity is cheaper. The participants in the symbol survey were presented with the five symbols seen in figure 6.8a-e and asked to state which one they preferred and if they had any additional comments.

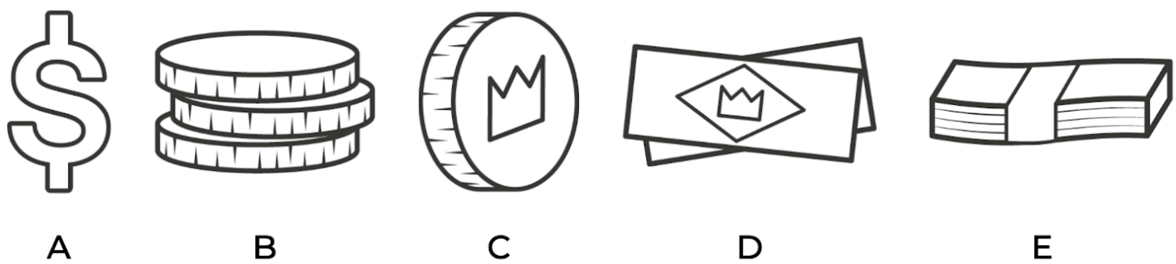


Figure 6.8a-e. Five symbols for a good economical choice.

The result showed that the participants preferred symbol B, closely followed by A. However, several participants argued that they did not really prefer any of them as they struggled with connecting them to saving money, but rather connected them to spending money or money in general. It was further stated that physical money is slowly disappearing and that a symbol resembling a coin or a money bill would therefore be at risk of becoming obsolete in a few years. However, several participants gave the proposal of a piggy bank as a better fitting option for saving money. Considering this, and that Eliq's current solution uses a piggy bank as a symbol for a good economical choice, an entirely new symbol was developed. The chosen symbol is shown in figure 6.9.

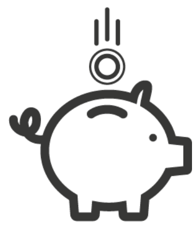


Figure 6.9. Good economical choice.

Good environmental choice

The symbol for a good environmental choice is thought to be used mainly when the user is making choices on what to prioritise when charging their electric vehicle. However it might also be used in other places in the app further on. The participants were presented with the five symbols in figure 6.10a-e and asked to state which they preferred and if they got any additional thoughts.

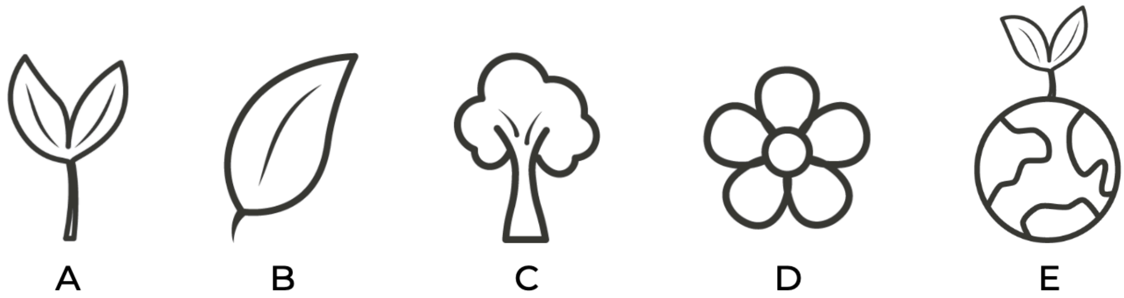


Figure 6.10a-e. Five symbols for a good environmental choice.

Figure 6.11. Good environmental choice.

The result showed that the majority of the participants preferred symbol E. Furthermore, A and B got approximately a quarter each of the votes while no one preferred C or D. Considering the result of the questionnaire it was decided that E would best symbolise a good environmental choice. There were however concerns regarding if E contains too many details and would be cluttered on a smaller scale. The final version of the symbol has therefore been redesigned to a more simple and scalable version with the globe and the sprout being more similar in size. The final version is shown in figure 6.11.

Wind power

The symbol for wind power is meant to be used to showcase the current energy mix to the user to facilitate an understanding of how the used electricity has been derived. The participants were presented with the five symbols in figure 6.12a-e and asked to state which one they preferred and if they got any additional thoughts.

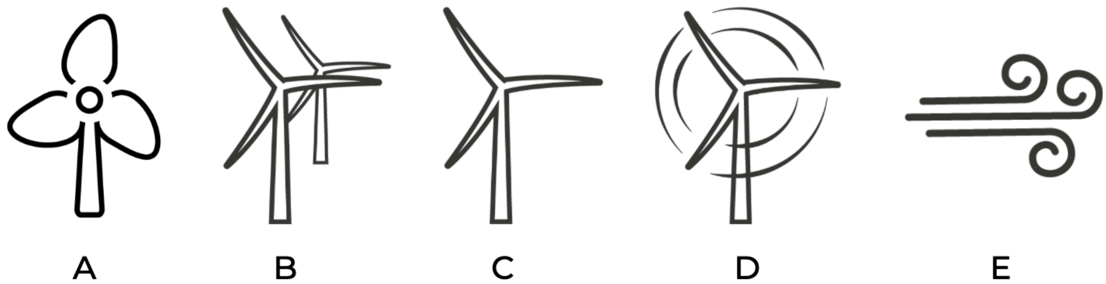


Figure 6.12a-e. Five symbols for wind power.

Figure 6.13. Wind power.

The result showed that a majority of the participants preferred B. However it was claimed that the wings of the mills in both B, C and D might be too pointy and that they would benefit from being rounder. One participant stated that a mix between the shapes of A and C would be ideal. It was stated that symbol A more resembles a flower or a smaller fan. Based on that it was decided against symbol A for wind power, however, the top of the symbol was decided to be used as a fan symbol in the EV part of the solution. Comments regarding E were that it symbolises wind very well, but not necessarily wind power. Based on the result, the final version is a rounder and more simpler version of B, shown in figure 6.13.

Hydro power

The symbol for hydro power will be used in the same way as the symbol for wind power. The participants were shown the four symbols in figure 6.14a-d.

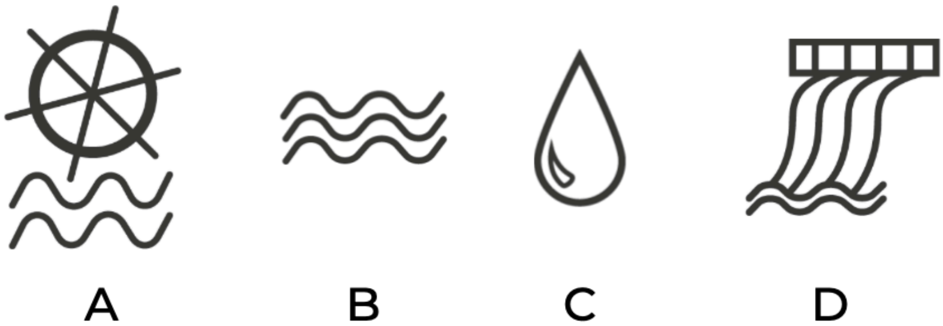


Figure 6.14a-d. Four symbols for hydro power.

The result showed that a majority of the participants preferred symbol D, followed by symbol B. It was argued that A might be confused with boats, and that B and C are not that strongly connected to hydro power, but rather just water on its own, and that symbol D might be unclear unless you know what it is. The participants were shown the symbols without a context, but in the final solution the context will facilitate the understanding of the symbols. Symbol D was chosen to symbolise hydro power, but the design has been simplified. The final version is shown in figure 6.15.

Figure 6.15. Hydro power.

Bioenergy

The symbol for bioenergy will be used in the same way as the symbol for wind - and hydro power. The participants were shown the five symbols in figure 6.16a-e.

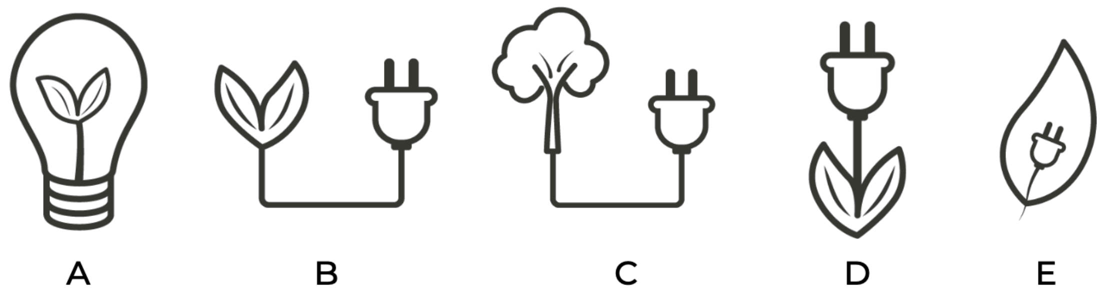


Figure 6.16a-e. Five symbols for bioenergy.

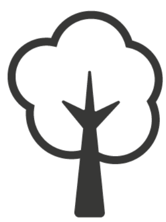


Figure 6.17. Bioenergy.

The result showed that most participants preferred symbol A, closely followed by B and C. There were however concerns that the sprout used in both A and B is too similar to the symbol for sustainability, which might lead to users mistaking bioenergy for the most environmentally friendly energy option. Furthermore, a few participants argued that they did not prefer any of them as none were clearly resembling bioenergy. With this in mind, the design of the symbol for bioenergy was rethought and taken back to basics. The final design of the symbol is shown in figure 6.17 and resembles a tree.

Nuclear power

The symbol for nuclear power is to be used when showing the energy mix to show what energy is derived from nuclear power plants, like the symbols for wind, hydro and bioenergy that was previously presented. The participants were presented with the four symbols shown in symbol 6.18a-d.

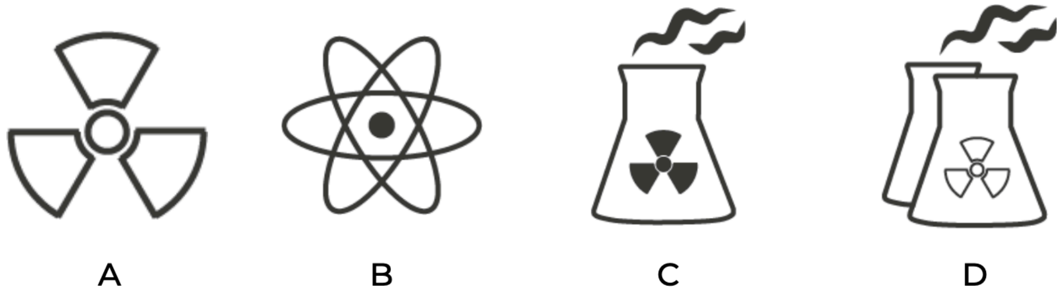


Figure 6.18a-d. Four symbols for nuclear power.

The results showed that option B was the most popular followed by A, C and lastly D. Some people thought that the symbol used for radioactivity used in option A, C, and D makes the symbol frightening. There were also comments that only using the symbol for radioactivity as in option A, can make people confuse it for wind power. One participant stated that option A, C and D have negative implications while B have positive ones. Option C and D were thought to be less neutral than the rest. Despite this, option D was chosen since it matches the options for wind and hydro power better. The smoke was removed in order to make it more neutral and the shape was adjusted to be more similar to an actual nuclear power plant and less like an Erlenmeyer flask. The final version of the nuclear power-symbol is shown in figure 6.19.

Figure 6.19. Nuclear power.

Solar power

The symbol for solar power is to be used both for visualising the part of the energy mix from the grid that is derived from solar power and also to symbolise the user's own solar panels if the user has solar panels installed. In that case the production from solar panels will have its own page and be accessible from the

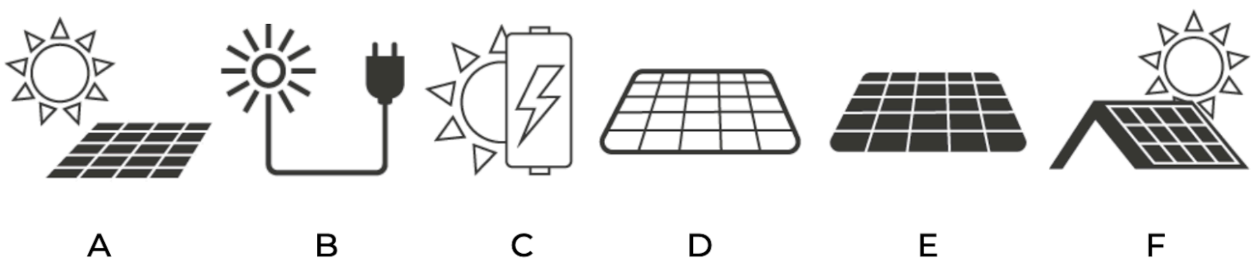


Figure 6.20a-f. Six symbols for solar power.

bottom menu. The solar power symbol will be in the menu to indicate that information regarding the solar panels can be found there. The participants were presented with six symbols shown in figure 6.20a-f.

The result showed that option B and F were the preferred ones. There were however some concerns expressed that B could be confused for other electrical symbols and that F could be confused with just a sun over a regular roof. Option A was also fairly popular and C received some votes as well. There were however no votes for D or E. Some people believed only a sun would be enough.

Based on the result and the critique against B and F, option A was chosen since it received no negative comments and it is similar to option F which got the second most votes. Furthermore, since the symbol is supposed to symbolise both installed solar panels on the house and a source of the energy mix from the grid, F was ruled out since it mainly represents domestic solar power facilities. The solar panels used to generate energy to the grid on a national level are generally not situated on rooftops. Option B was eliminated since it does not have the same style as the options for the other energy sources. Option A was changed to have less lines in order to make it simpler and easier to see in a small format. The sun was also moved closer in order for the sun and the panels to make up a more unified unit. The final version is shown in figure 6.21.

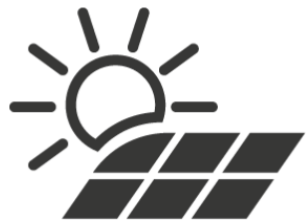


Figure 6.21. Solar power.

Electric vehicle

If the user owns an EV the information regarding the EV will be on a separate page accessible from the bottom menu and the EV symbol will in such case indicate where the page can be found. The participants were presented with the six symbols shown in figure 6.22a-f.

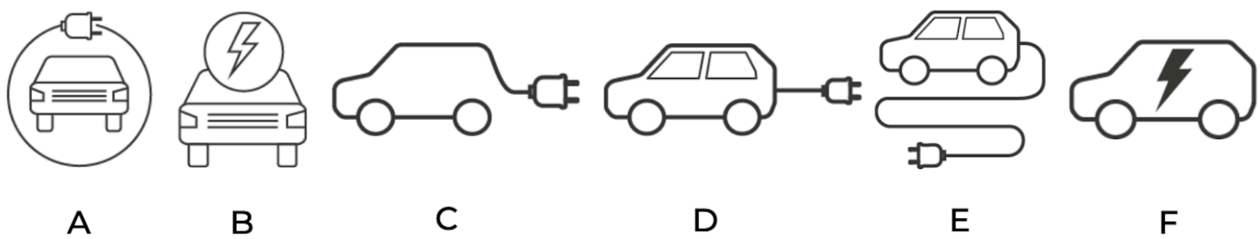


Figure 6.22a-f. Six symbols for EV.

The results showed that option C was by far the most preferred symbol with the majority of the votes followed by option F with around a quarter of the votes. The remaining options all received a few votes each. People expressed that option C is simple and schematic. Due to the strong preference for C that option was chosen. The shape was however adjusted to make the car give a more modern appearance, as can be seen in figure 6.23.

Figure 6.23. EV.

Electric grid

The electric grid symbol is thought to be used when visualising the energy flow in the household, to show when energy flows from the grid to the house, or possibly from the house to the grid if the user produces electricity and sells it. The participants were presented with the four symbols shown in figure 6.24a-d.

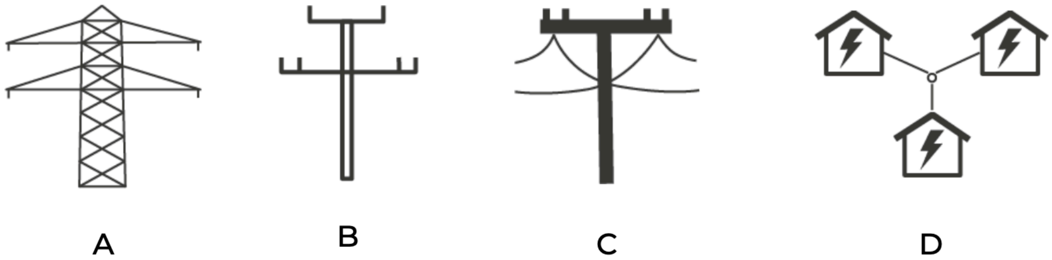


Figure 6.24a-d. Four symbols for electric grid.

The result showed that option A was the most popular with almost half of the votes. Option D and C were pretty even runner ups with around a quarter of the votes each. Option B was the least preferred choice with only a few votes. Based on the result, option A was chosen. The final design is however simplified with fewer lines to make the symbol, as can be seen in figure 6.25.

Figure 6.25. Electric grid.

Achievements

If the user reaches goals and unlocks new achievements there needs to be a way to symbolise this. Five different ways to show achievements seen in figure 6.26a-e were developed and presented to the participants.

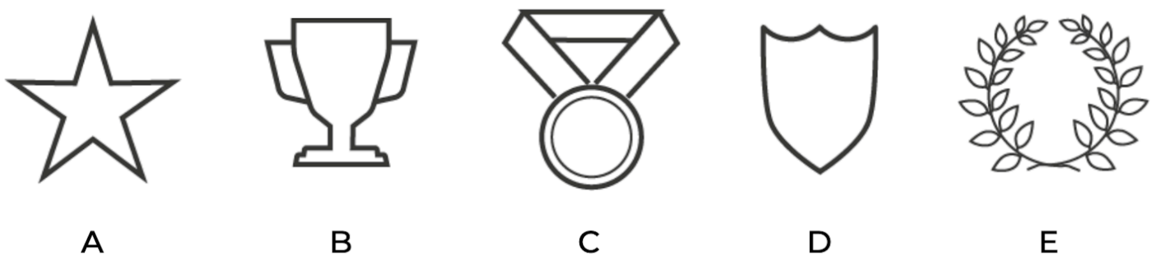


Figure 6.26a-e. Five symbols for achievements.

The result showed that option B was the most preferred version with almost half of the votes. The next most preferred option was C with a third of the votes. Some people mentioned that several different achievement options could be used but some for smaller achievements and some for larger achievements. There were also comments that colours like bronze, silver and gold could be used instead to symbolise the greatness of the achievement. Based on the result option B was chosen since it was the participants' favourite and it was decided to use colours to indicate how big the achievement is. The chosen option was streamlined and simplified as can be seen in figure 6.27.

Figure 6.27. Achievements.

Charging

If the user owns an EV showing the current charge is one of the most fundamental functions which can be shown in several ways. Four different options which can be seen in figure 6.28a-d were developed and presented to the participants.

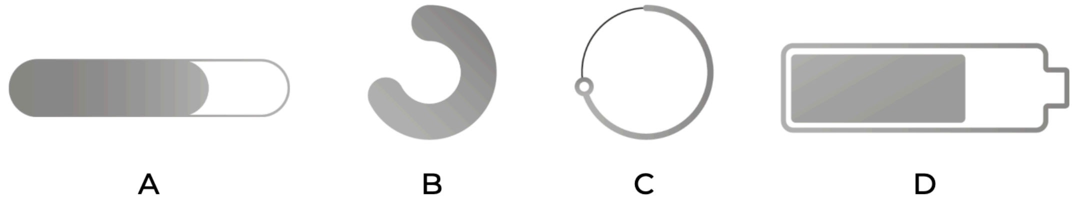


Figure 6.28a-d. Four symbols for charging.

Option D was the favourite version with the majority of the votes. It was relatively close between the remaining options. Participants mentioned that what they preferred depended on what type of charging it was. If it was simply a battery, option D would be preferred but if it involved charging as a process then option B or C would be better. Option B was eventually chosen despite option D getting more votes. Option B was however the second most preferred option and was mentioned to be suitable for showing the charging process. The main reasons for choosing option B were however that the round form was suitable for showing the exact charge percentage in the middle which would otherwise disrupt the view in the horizontal versions A and D and it also enabled showing the charging limit in a more intuitive way than the other options. It was also to keep consistency with the other functions as there are other circular designs in the app. Option B was adjusted slightly by making the ring a bit thinner and the area inside bigger in order to make space for charge percentage text (figure 6.29). A white ring was also added to symbolise the charging limit.

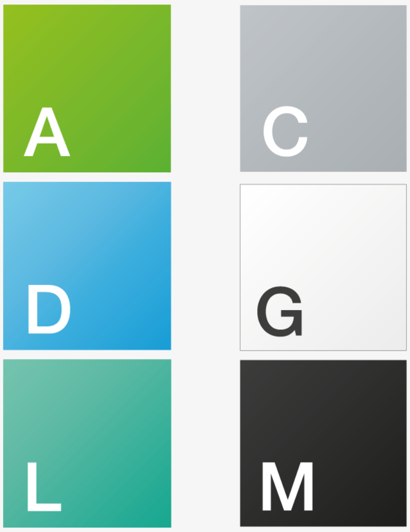
Figure 6.29. Charging.

6.4.2 Colours

The result is shown and discussed on the next page, as well as a motivation to which colour was chosen to symbolise each attribute. The three colours that received the most votes are shown below, with the one with most votes at the top and a corresponding text to which colour was chosen for each attribute.

ACTIVE

A got the most votes and it was stated by participants that green is recognised as the colour often used to show that electronic devices are on. However, it is believed that green is widely associated with sustainability, especially as the solution has a sustainability focus. L has therefore been chosen so symbolise *Active* in the solution.

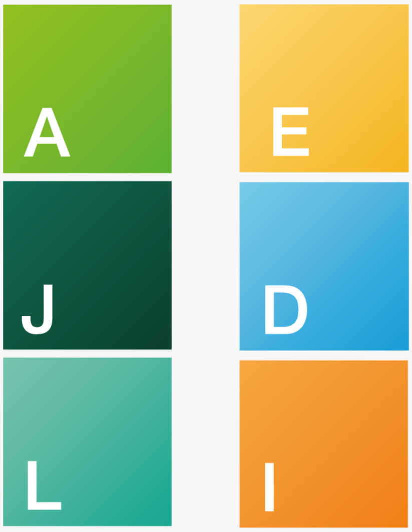


NEUTRAL

C, the grey colour, received more than half of the votes in the questionnaire. As grey is achromatic and widely used as a neutral colour, C was chosen to symbolise *Neutral* in the solution.

SUSTAINABILITY

The three green colours together received almost all of the votes, with A being the favourite. Green is a colour strongly associated with sustainability and the environment, and A has therefore been chosen to symbolise *Sustainability*.



ELECTRICITY CONSUMPTION

To symbolise electricity consumption, E got the most votes. However, both E and I are strongly associated with solar power. D has therefore been chosen to symbolise *electricity consumption*.

SOLAR POWER

E received the majority of the votes from the participants and it was stated that as the sun is yellow, yellow would be preferred for solar power. However, the contrast would be too low for white text on a yellow background or vice versa. Colour I has therefore been chosen for *solar power*, as it is similar to E and got a higher contrast in combination with white. However, yellow will still be used in diagrams in combination with D for electricity consumption.

ELECTRIC VEHICLE

The three most popular colours to symbolise EV were colours that appeared for several other attributes. As blue is a colour widely used for EVs and as N was the fourth most voted for colour, N was finally chosen to symbolise *electric vehicle*.

7

DESIGN IMPLICATIONS

Based on the findings from the *market analysis*, the *exploration*, and the *ideation* implications for the further design work were established. These are presented in this chapter, as guidelines and insights.

7.1 Aim

The main purpose of this chapter is to collect and present all findings before initiating the second explorative phase of the project. The findings will guide the design work, facilitate the concept development and will also be used as evaluation criteria.

7.2 Guidelines

The main findings have been summarised in a set of guidelines and insights presented in this section. For a more in depth presentation of the findings with corresponding guidelines, see Appendix C. The guidelines have been divided into nine categories presented in the sections below. Each guideline has also been assigned a prioritisation on how important they are to the final solution. The prioritisation scale has been set to 1-3 and have the following meaning:

- 1: Crucial to include to satisfy the users' basic needs and requirements.
- 2: Desirable to include in the final solution.
- 3: Out of scope for this project, but still important to remember for future, continuous development.

In addition to the prioritisation, the guideline's origin has been included. This could be both a finding that inspired a guideline or that a user specifically expressed a need or desire for a certain function. The origins have been organised in six categories corresponding to a certain colour and position in the colour chart, as follows:

7.2.1 Total consumption

In total ten guidelines were developed regarding total consumption of electricity, they are presented in table 7.1. Most of them originate from the *market analysis*, but also from the *literature study*, *questionnaire survey* and the *interviews*.

Table 7.1. Guidelines regarding information on total consumption.

Guideline		Prio	Origin
1.1	Provide total consumption of the month thus far	1	● ● ● ● ○ ○
1.2	Provide total cost of the month thus far	1	● ● ● ● ○ ○
1.3	Visualise how consumption is distributed throughout the day	1	● ○ ○ ● ○ ○
1.4	Provide detailed and personalised visualisation of the distribution of electricity	2	○ ● ○ ● ○ ○
1.5	Separate EV consumption from the household consumption	2	● ○ ○ ● ○ ○
1.6	Enable consumption comparisons between time periods (hours, days, weeks, months, years)	1	● ● ○ ● ○ ○
1.7	Provide correlation between consumption and external factors (e.g. temperature, daylight)	3	● ○ ● ● ○ ○
1.8	Provide monthly and weekly consumption reports	3	● ○ ○ ○ ○ ○
1.9	Provide history of EV charging	2	● ○ ● ○ ○ ○
1.10	Provide monthly cost of EV charging	2	● ○ ● ○ ○ ○

7.2.2 Real time data

Regarding real time data, three guidelines were developed, they are presented in table 7.2. They originate from the *market analysis*, the *literature study*, the *questionnaire survey* and the *interviews*.

Table 7.2. Guidelines regarding real time data.

Guideline		Prio	Origin
2.1	Provide real time consumption data	1	● ● ○ ● ○ ○
2.2	Provide information on current charge [EV]	1	● ○ ● ● ○ ○
2.3	Provide real time consumption data	1	● ● ● ● ○ ○

7.2.3 Awareness

Regarding awareness, nine guidelines were developed, they are presented in table 7.3. The majority of them are partly derived from the *interview study*. Furthermore they originate from the *market analysis*, the *literature study* and the *questionnaire survey*.

Table 7.3. Guidelines regarding awareness.

Guideline		Prio	Origin
3.1	Provide information of consumption of specific actions	3	○○○●○○
3.2	Provide information of cost of specific actions	3	○○○●○○
3.3	Visualise gain in different units (SEK, kWh, CO_2eq)	1	●●●●○○
3.4	Provide clear visualisation of improvements/ worsenings	1	○●○●○○
3.5	Provide forecast on consumption based on earlier behaviour	2	●○○○○○
3.6	Provide positive encouragement when user has made improvements	2	○●○●○○
3.7	Provide trivia on how one can decrease consumption	3	●●●●○○
3.8	Provide individual advice on how to decrease consumption	3	●●●●○○
3.9	Provide information on repayment of solar power	2	○●○●○○

7.2.4 Grid information

In total five guidelines were developed regarding grid information, they are presented in table 7.4. They have mostly been derived from the *interview study*, but also from the *market analysis*, the *literature study* and the *questionnaire survey*.

Table 7.4. Guidelines regarding grid information.

Guideline		Prio	Origin
4.1	Provide information on power tariffs.	1	○●○●○○
4.2	Highlight what source(s) the electricity is derived from	2	○○○●○○
4.3	Show CO_2eq/kWh for the electricity mix of the household	2	○○○●○○
4.4	Provide information of how price of electricity varies over time	1	●○●●○○
4.5	Provide positive encouragement when peak demand is avoided	3	○●○●○○

7.2.5 Control

For the category control, five guidelines have been developed and are presented in table 7.5. The majority originates from the *market analysis*, but also from the *literature study*, the *questionnaire study* and the *interviews.*

Table 7.5. Guidelines regarding grid information.

Guideline		Prio	Origin
5.1	Enable remote adjustments of heat [EV]	3	○○○●○○
5.2	Enable adjustments of maximum charge [EV]	1	●●○●○○
5.3	Enable scheduling of charge to times when electricity is cheap or low demand [EV]	1	●○●○○○
5.4	Enable individual goal-setting	2	●●○○○○
5.5	Provide updates on the set goal	2	●●○○○○

7.2.6 Solar power production

For solar power production, four guidelines have been developed. They are presented in table 7.6. All of them originate from both the *market analysis* and the *interview study*. The first two also originate from the *questionnaire survey.*

Table 7.6. Guidelines regarding solar power production.

Guideline		Prio	Origin
6.1	Enable prosumers to continously follow production	1	●○●●○○
6.2	Enable production comparisons between time periods (hours, days, months)	1	●○●●○○
6.3	Provide an overview of total production from solar panels, consumption, sold and bought electricity	1	●○○●○○
6.4	Visualise production from individual solar panels	2	●○○●○○

7.2.7 Notifications

During this thesis project it was decided to not focus on notifications, however notifications are an important part of the user experience of an app and have therefore been included in the guidelines anyway. For future reference they have been assigned a prioritisation. In total five guidelines were developed regarding notifications and they are presented in table 7.7. They originate from the *market analysis*, the *questionnaire survey* and the *interviews*.

Table 7.7. Guidelines regarding notification.

Guideline		Prio	Origin
7.1	Notify user when consumption is unusually high, and what the cause is	1	● ○ ○ ● ○ ○
7.2	Notify user if charging has stopped unexpectedly and why [EV]	1	○ ○ ○ ● ○ ○
7.3	Notify user when new information is available in the app	1	● ○ ○ ○ ○ ○
7.4	Notify user when the energy mix deviates from normal	2	○ ○ ○ ● ○ ○
7.5	Notify user when demand for electricity is high	2	○ ○ ● ● ○ ○

7.2.8 Visualisation

To facilitate the design of the solution, ten guidelines regarding visualisation have been developed and are presented in table 7.8. They mostly originate from the *interviews* or the *symbol survey*, but a few of them are also inspired by the *market analysis* and the *design theory*.

Table 7.8. Guidelines regarding visualisation.

Guideline		Prio	Origin
8.1	When different measurements are visualised in the same diagram, use different types of charts to increase clarity	2	○ ○ ○ ● ● ○
8.2	When different measurements are visualised in the same diagram, charts should not severely cover each other	1	○ ○ ○ ● ● ○
8.3	Use a neutral colour for charts which cannot be influenced by the user	1	○ ○ ○ ● ○ ●
8.4	When visualising production from individual solar panels, darker colours shall symbolise higher solar irradiation	2	○ ○ ○ ● ○ ○
8.5	Malfunctioning solar panels shall be visualised in a deviating way	1	○ ○ ○ ● ○ ○
8.6	Use yellow-orange for attributes regarding solar power	2	● ○ ○ ● ○ ●
8.7	Use dark-blue for attributes regarding EV	2	○ ○ ○ ○ ○ ●
8.8	Use grey for neutral and/or non-active options	2	○ ○ ○ ● ○ ●
8.9	Use turquoise for clickable and/or activated options	2	○ ○ ○ ○ ○ ●
8.10	Use light blue to symbolise electricity consumption	2	○ ○ ○ ○ ○ ●

7.2.9 Usability

To enhance the solution's usability, ten guidelines regarding usability have been developed and are presented in table 7.9. All of them originate, at least partly, from the *design theories*, but a few of them are also inspired by findings in the *market analysis* or the *symbol survey*.

Table 7.9. Guidelines regarding usability.

Guideline		Prio	Origin
9.1	Be consistent with choice of colour for attributes	1	○ ○ ○ ○ ● ○
9.2	Use recognisable symbols	2	○ ○ ○ ○ ● ○
9.3	Symbols shall all have a similar design language	2	○ ○ ○ ○ ● ●
9.4	Avoid displaying several attributes at the same time, in consideration of user resources	2	○ ○ ○ ○ ● ○
9.5	Make the most important information the most noticable	1	○ ○ ○ ○ ● ○
9.6	Make it obvious which attributes are clickabe	1	● ○ ○ ○ ● ○
9.7	Make it obvious what option is chosen	1	● ○ ○ ○ ● ○
9.8	A novice user shall be able to easily navigate the app	2	○ ○ ○ ○ ● ○
9.9	Texts smaller than 17 pt shall have a minimum colour contrast ratio of 4,5:1	1	○ ○ ○ ○ ● ○
9.10	Bold texts or texts larger than 17 pt shall have a minimum colour contrast ratio of 3:1	1	○ ○ ○ ○ ● ○

7.3 Insights

The study also resulted in a collection of insights that will be presented in this section. The insights are not as important for the design work itself, but are all important for designers to keep in mind when working with electricity monitoring.

The invoice is often considered insufficient, cluttered and incomprehensive

The consumers only receiving an invoice from their electricity provider expressed complaints countless times in both the questionnaire and during the interviews. It is at many times considered cluttered and difficult to comprehend. Furthermore, the electricity consuming behaviour and the feedback from the invoice is distant in time, making it troublesome to connect the two.

Many consumers are unaware that they have access to an app from their electricity retailer

It happened several times during the interview study that the interviewee told that they used a certain electricity retailer that offers an app, whereafter they were asked whether they used their app to monitor electricity consumption and it appeared they were unaware the app existed at all. Electricity retailers that do offer an app have a lot to gain if they market their app to a larger extent.

It is a challenge to maintain engagement of the app users over time

The prosumer-participants of both the questionnaire and the interview study argued that their interest in monitoring the production from their solar panels declined over time. When installing the facility, their ambition was to follow the production each day, but as the feeling of novelty had worn off they now only check the production once a month or even more rarely. The same goes for users without a solar power facility; it is a challenge to keep them engaged and interested in using the app over time.

Making the log-in process simple is crucial for high engagement

When asked if a mobile application was preferred over a website to monitor electricity use, the participants argued that it is more accessible to log in to an app than to go to a website and log in to an account there, and that they would probably use that less often. It can therefore be implicated that an easy log-in process, whether it is an app or website, is crucial for high use frequency. A complicated log-in requiring several steps will likely decrease the user's motivation to log in at all.

People get more motivated if their electricity consumption is categorised

A prevalent issue both from other studies analysed and from the interviews and questionnaire was that people in general lack an understanding of how their behaviour affects their electricity consumption. Categorising the electricity consumption according to where or for what it has been used, including how much and during what times of the day will increase the consumers knowledge and understanding of their consumption and thus also contribute to increased motivation. It is furthermore crucial that the information presented to the user is that of their own consumption, and not general information generated from algorithms, as that could affect the trustworthiness of the app if it becomes apparent to the user.

A visually appealing app is important for high use frequency

It was argued by several participants that they would be more motivated to use a visually appealing app for electricity monitoring, in comparison to one that had not put as much effort into the design. Furthermore, it is important that the design language and colours used in the app aligns with the values of the company, and that it is easy to understand and use, hence has a high usability.

People prefer, and find it more relevant, to compare their consumption with their own consumption history than to compare with similar homes

The result of previously conducted studies on the topic of comparison with similar homes have come to contradicting conclusions. The participants of the studies conducted in this thesis project argued that even though it might be interesting to see how one compares to similar homes, it is much more relevant and motivating to compare and compete with oneself. Furthermore it was stated that it is important to remember that every household has different possibilities and circumstances limiting or enabling them to affect their consumption in a certain way, meaning that the comparison between households must take many factors into account to be relevant and fair to everyone.

Feedback motivates and triggers reflection

Getting real-time feedback is crucial to develop an understanding of how actions will affect one's electricity consumption. If the feedback reaches the consumer with the invoice a month later, the consumer has likely forgotten what they did and what appliances were on that caused high consumption on certain days. If the feedback reaches the consumer in real-time, or just shortly after, they are able to reflect on their behaviour to a larger extent, and are also likely more motivated to change the behaviour if needed.

Participants are unwilling to make changes that would affect quality of life

Results from previously conducted studies, as well as the studies conducted in this thesis project found that people are willing to change their behaviour, but only to a certain extent. People are likely to prioritize their comfort and quality of life prior to lowering the electricity usage, especially if the effect on their bill is minimal. It is therefore a challenge to show the user the environmental benefits of decreasing or shifting their electricity usage, and thereby motivating them to make sustainable changes.

Many consumers feel constrained in when to use electricity, as they only spend a few waking hours at home during the week

Some participants argued that it was more important when the electricity was used than how much. Expert 2 also explained that during a large portion of the day, the capacity of the electric grids that are utilised are low and thereby it is of less importance how much electricity the individual households use. However, as stated by some participants, people usually work during the whole day thus spending the day away from home, then come home and cook, do laundry, do the dishes, take a shower and then go to bed. The possibilities to shift the electricity use during weekdays are thus limited, which need to be kept in mind.

For prosumers, high production of solar power often does not correlate with hours of high demand

A problem many prosumers encounter is that the solar panels produce the most power in the middle of the day, which is usually when people are away from home and thus do not use electricity. Later in the afternoon and in the evening when people are arriving home and start to use electricity, the power production from the panels decreases and stops as the sun sets. The lack of possibilities to store electricity for later use thus force prosumers to sell a large portion of their produced electricity and for them to re-buy it at other times when they need it. This is a challenge to keep in mind, as prosumers are limited as to how much of their electricity they can use due to external factors.

People are motivated to decrease their environmental impact due to many different reasons

The participants of the user studies conducted in this thesis project were asked what environmental destruction motivates them to decrease their impact the most. The result varies greatly, from garbage in the oceans and dying of coral reefs to deforestation, animals suffering and health consequences for people breathing in polluted air. As far as motivation to decrease electricity consumption goes, the economy and environment are the most common motivators, but people are also motivated by making it a challenge for themselves to decrease the consumption, avoiding a sedentary lifestyle or simply disliking inefficient appliances. It can thus be concluded that people are motivated by a large variety of reasons.

People are motivated to install solar panels or buy an EV due to many different reasons

The same goes for this insight as for the previous one; people are motivated by a variety of reasons. The environment and the economy are common motivators to install solar power or get an EV, but people also want to be self-sufficient in electricity production and hence in fuel for their car or they see it as an investment for the future. Some are just curious about the technology, want to participate in the environmental debate or aim for a certain social status among friends and neighbours. At many times it is a combination of many reasons that motivate people, but it can however once again be concluded that people are motivated by a lot of different reasons.

8

CONCEPT DEVELOPMENT

This chapter will present the concepts that were developed based on the guidelines and insights. In the following sections the aim of the phase, the procedure and the result will be presented.

8.1 Aim

The aim of the concept development phase was to ideate and create concepts of what a future solution could look like based on the findings from previous phases. The ideation was conducted with pen and paper, whereafter digital prototypes of concepts were created.

8.2 Procedure

The methods used in the concept development phase were brainstorming and braindrawing in order to come up with solutions of how to visualise different functions. Furthermore, prototyping was conducted where ideas were created digitally in Adobe Illustrator and put together into a clickable prototype in Adobe XD.

8.2.1 Ideation

In order to come up with ideas of how to visualise the different functions which had been identified and documented in the guidelines a combination of brainstorming and braindrawing was done. The focus was on one theme at a time. First there was an individual session where ideas around a certain theme were created and documented individually. This was done until it felt suitable to stop, usually when it felt difficult to individually come up with new ideas. Thereafter a presentation and discussion of the ideas followed. From this, new ideas were added and some of the old ideas were revised or combined. Sometimes completed themes were revisited again if new ideas came up. The ideas were drawn by hand on paper with ink and coloured pens. Some ideas were further described with text.

For the themes which had already been ideated around and used as mediating tools in the interviews during the exploration phase, this was a second round of ideation where new ideas were created and old ideas were revised based on the feedback from the interviewees.

8.2.3 Prototype

The most promising ideas from the ideation session were digitally made and refined in Adobe Illustrator, using the symbols and colours decided upon from the symbol survey, presented in section 6.4. As the paper sketches from the ideation mostly consisted of relatively loose ideas it was in the prototyping where more detailed nuances were determined, such as line width, sizes and distances between objects. For some functions different options were made in Adobe Illustrator before deciding which one to go through with. For several functions, changes or adjustments were made along the way. The functions were made to have a cohesive appearance and common design language.

The different functions were then put together into a clickable prototype in Adobe XD. Different screens and connections between the screens were made so that if, for instance, the solar panel symbol on the bottom menu is clicked on, the prototype will move to the screen for solar panels. Diagrams which were too wide to fit into the screen were made horizontally scrollable. The size of the screen was made to fit an iPhone X and other details which would generally be visible on an iPhone X screen such as time, battery and Wi-Fi were also added in Adobe XD.

8.3 Concepts

In this section the concept which was developed will be explained and visualised with illustrations of the prototype. Each function is explained separately but they are grouped together in bigger themes which are as follows: electricity distribution, electricity consumption, solar power production, electric vehicle and miscellaneous. The guideline(s) each function fulfils are included, however the guidelines for visualisation and usability have been excluded since they apply to all functions.

8.3.1 Electricity distribution

In this section two concepts regarding electricity distribution and flow will be presented. The two concepts illustrate the same information, but in different levels of detail.

House

Guidelines: 1.5, 2.1

When signing in to the current solution, the first thing the user sees is a 3D-illustration of a house. This occupies a large part of the home screen, without giving the user any useful information, however it is believed to contribute to an appealing and playful impression of the app. During the ideation ideas emerged if it was possible to retain the house to maintain the positive impressions it contributes with, but also add useful elements of information. When evaluating flow of electricity with users during the *Exploration* phase, less clutter was appreciated, as well as being able to get a straightforward overview. With this in mind, the house on the home page has been developed further to include simple and straightforward information on flow of electricity between the sun, grid, house and EV. The yellow rays symbolise solar power, and the blue rays symbolise power from the grid. An example of this is shown in figure 8.1.

Flow of electricity

Guidelines: 1.4, 1.5, 2.1, 4.2, 4.3, 6.1, 6.3

When evaluating the ideas on flow of electricity, the pie charts for electricity distribution and energy mix were appreciated and perceived as pedagogical. The pie charts have therefore been retained, but developed further and with added symbols. Figure 8.2 shows the flow of electricity between the solar panels (top left), the house (bottom left), the grid (top right) and the EV (bottom right). Furthermore the energy mix of the household is displayed as well as the distribution in the home. The blue rays show electricity from the grid and the yellow rays show the solar power. The unit used is Watt. During the *Exploration* phase it was found that it is appreciated to separate the EV from the rest of the household consumption as it is such a big consumer and that the total consumption in the house could become misleading otherwise.

The pie chart displaying the distribution of electricity within the home can also be used to show what the distribution has looked like over a period of time, for example over a day, a month or a year.

8.3.2 Electricity consumption

In this section three concepts regarding electricity consumption are presented. The concepts regard how to show current consumption, consumption statistics and how to give visual feedback on consumption.

Current consumption

Guidelines: 1.3, 1.5, 2.1, 4.1, 6.1

To provide the user with a quick overview of the consumption of the last 24 hours, the circular version discussed in section 6.3 was further developed. In the previous version, the strain on the grid was an important part. This has however been abandoned and a version containing information on power tariffs has instead been developed. The power tariffs do, in a way, also display when the strain on the grid is high and low, as they are only active during the day when the strain is higher. The current time will always be upwards, and the transparent bars to the right symbolise the hours furthest back in time, i.e. 23 hours ago. In the centre of the circle the total consumption of the last 24 hours are displayed, and the bars around are showing how much the household has consumed each hour. The colours used for the bars have been reassessed. The lighter blue symbolise consumed electricity purchase from the electric grid, the yellow symbolised consumed electricity from the solar panels and the dark blue, smaller bar inside the larger bars display when the electric vehicle has been charged. The redesigned concept is shown in figure 8.3. From this view it is intended that the user will be able to reach more extensive information.

Consumption statistics

Guidelines: 1.1, 1.2, 1.3, 1.5, 1.6, 2.1, 3.5, 4.1, 4.4

To enable the user to further compare different time periods in an intuitive way, Day -, Month - and Year views have been added. For all the views, the user will have the option to switch between what unit to display in the diagram, Kilowatt hours [kWh] or Swedish Krona [SEK]. Blue bars symbolise electricity purchased from the grid and yellow symbolises solar power.

The Day-view has similar information as the *Current consumption* presented previously (figure 8.3), but in a horizontal format and also shows the forecast as dashed lines. This is shown in figure 8.4. The monthly view shows the consumption day by day, with the bars being divided into blue and yellow parts showing to what extent electricity has been purchased from the grid and utilised from solar panels respectively. The dashed lines are a forecast, which is calculated based on previous use patterns, weather forecast and other factors affecting the consumption. The yearly view shows the consumption month by month, and is intended to have the same functions as the other views. When the user has chosen SEK, a line will display the cost for each hour, day or month. In the diagram in figure 8.5 the price is zero at times, which is because all electricity used during those hours come from solar panels, meaning no costs.

Feedback with polar bear

Guidelines: 1.1, 1.2, 3.3, 3.4, 3.5, 3.6

To visualise, in an intuitive way, that electricity consumption does have consequences on the environment, three alternatives were evaluated with users (further discussed in section 6.3). Based on the comments regarding the three options, the polar bear was chosen, however snow was added to further highlight the positive encouragement. It is believed that users will feel empathy for the polar bear to a greater extent than for the tree or the earth, and it is furthermore obvious that it is symbolic and not literal. When evaluated, the exact placement of the polar bear was not decided. During the ideation different placements were discussed, but it was finally placed in combination with a monthly overview which compares the consumption so far this month with the consumption during the same time period the previous year. An example of this is shown in figure 8.6.

8.3.3 Solar power production

This section presents four concepts regarding solar power production. The concepts regard how to show consumption and production in the same diagram, a compilation of sold and bought electricity, the status of individual solar panels and how to show the repayment of the investments.

Production and consumption diagrams

Guidelines: 1.1, 2.1, 2.3, 6.1, 6.2

The diagrams show the consumption and production in a daily, monthly and yearly view. Two different versions have previously been evaluated with users (further discussed in section 6.3) and the new design is based on the feedback and discussion. While there was no complete consensus regarding if there should be an extra graph in the diagram showing the net value of production and consumption, it was decided to go with the version without it since participants believed it was simpler and also because it was believed to be redundant if there were additional information tables. The version evaluated with users was in a daily view and the developed version which can be seen in figure 8.8 has been kept similar. Monthly and yearly views were also developed where the consumption is represented by blue bars and the production is represented as a yellow line with dots. The monthly view is shown in figure 8.7.

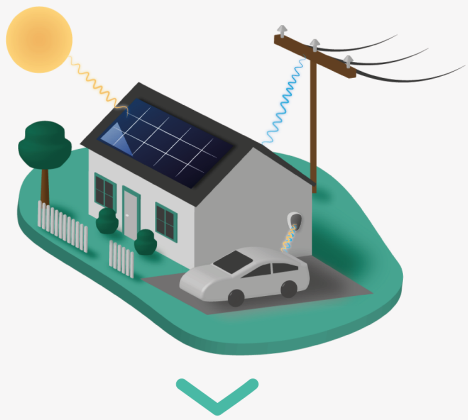


Figure 8.1. Electricity distribution, house

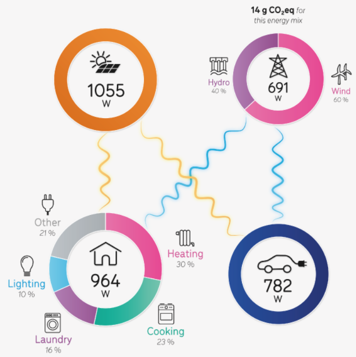


Figure 8.2. Flow of electricity

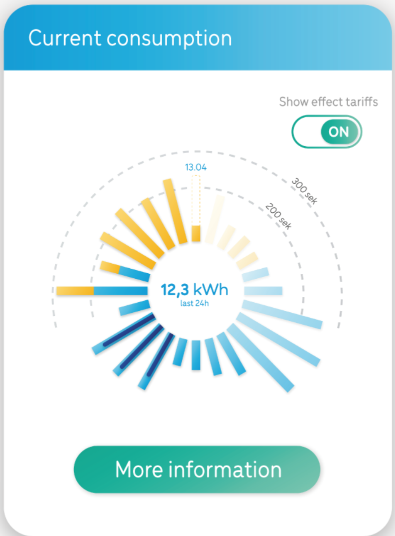


Figure 8.3. Current consumption

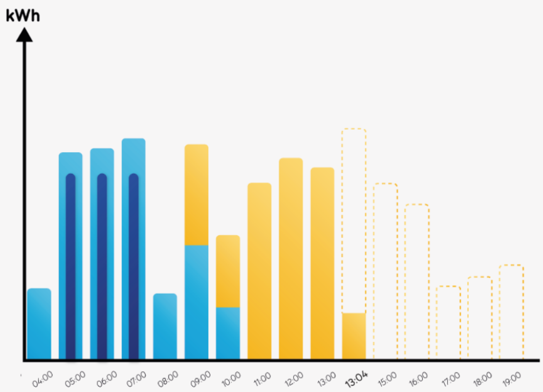


Figure 8.4. Consumption statistics - daily view, kWh

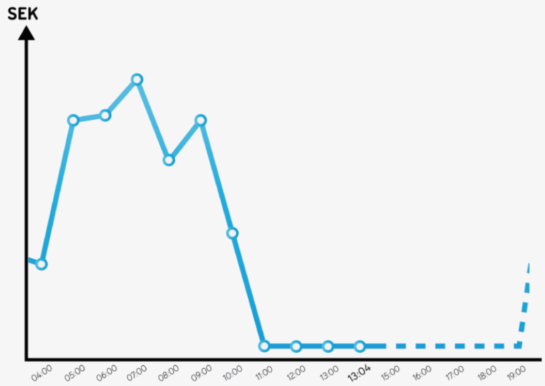


Figure 8.5. Consumption statistics - daily view, SEK

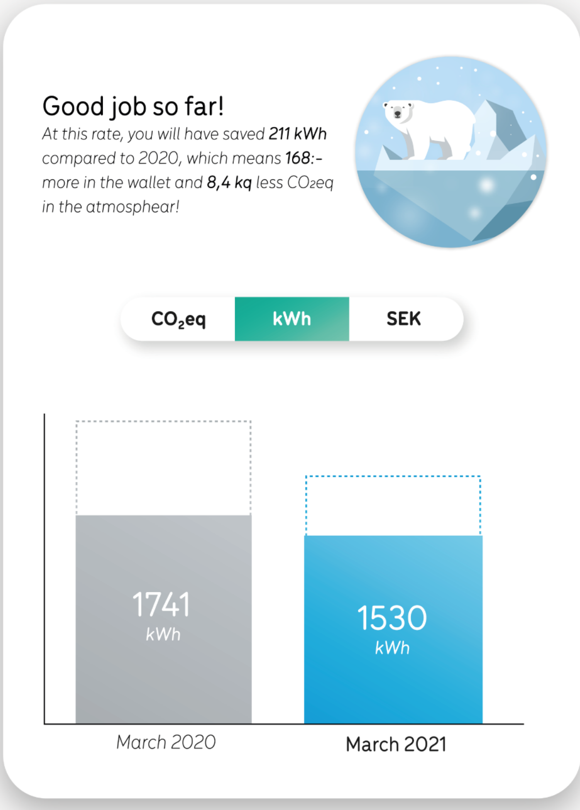


Figure 8.6. Feedback with polar bear

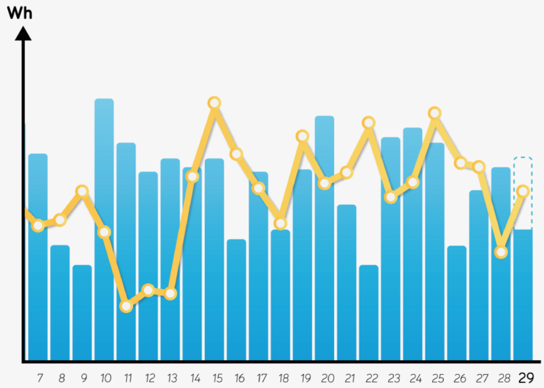


Figure 8.7. Consumption and production diagram - monthly view

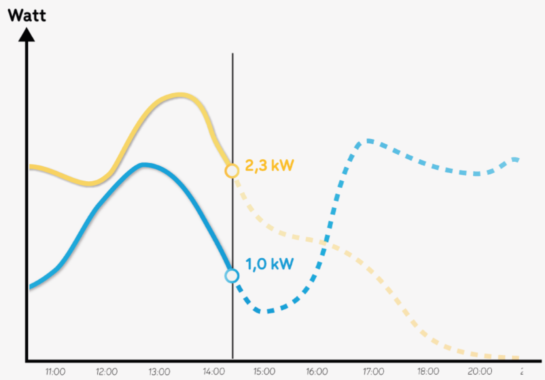


Figure 8.8. Consumption and production diagram - daily view

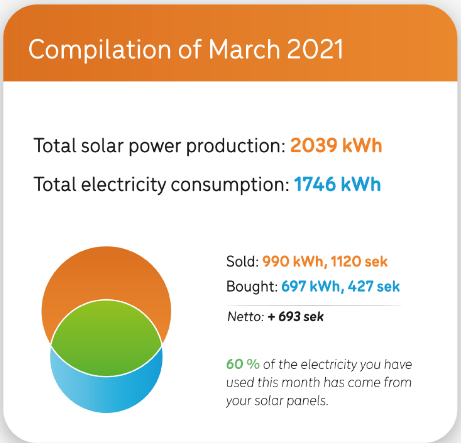


Figure 8.9. Compilation - monthly view

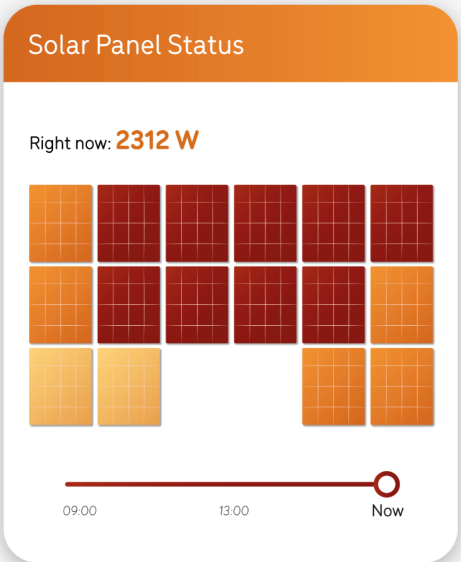


Figure 8.10. Solar panel status

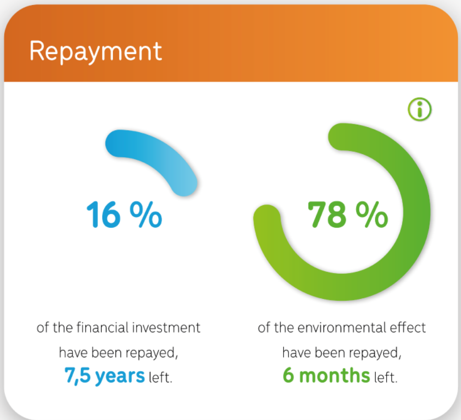


Figure 8.11. Repayment

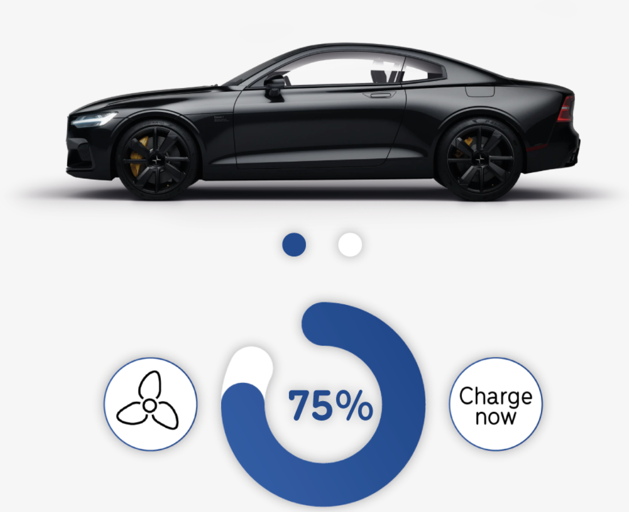


Figure 8.12. Overview at the EV page. Showing the car, AC, charging status and "Charge now" button.

Figure 8.13. Monthly charging cost

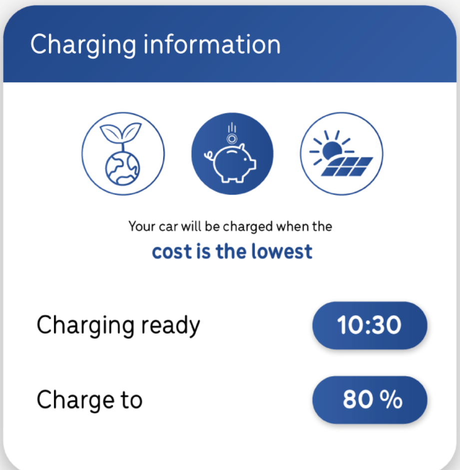


Figure 8.14. Charging information

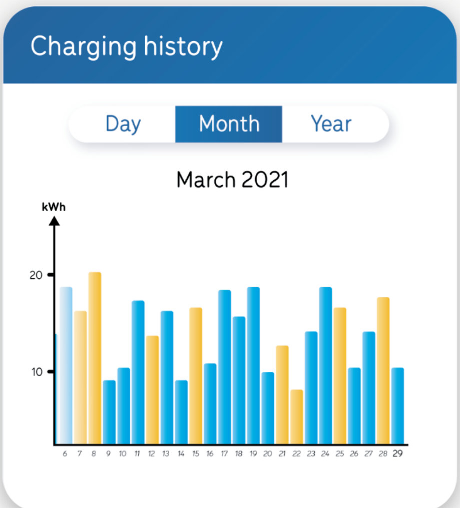


Figure 8.15. Charging history

Figure 8.16. Example of achievements/ goals.

Compilation

Guidelines: 1.1, 6.3

The compilation shows an overview of the production and consumption and net value in the monthly and yearly views (figure 8.9). A version of this was evaluated with users which is further discussed in section 6.3. The information participants were interested in seeing was bought, sold and net energy. The compilation was believed to be more important if the net value was not shown in the production and consumption diagrams. The compilation shows the total production and consumption so far of the current month or year, how much has been bought and sold and also the net value in monetary terms. An idea that came up during the evaluation was to have the text in the information table the same colour as the corresponding graph, which has been implemented with the exception of the yellow taking a darker more orange tone for visual clarity. Lastly, the green part in the Venn diagram shows how much of the electricity used comes from the owner's solar panels.

Solar panel status

Guidelines: 6.1, 6.4

To provide the user with a more in depth view of the production from their solar power facility the production from individual panels have been developed. As discussed in section 6.3, the participants preferred that the panels varied in colour based on their production. However, as every participant in the evaluation of the previous version of the solar panel status interpreted a dark colour as higher production it has been altered. Furthermore, the colour scheme has been changed to warm colours instead of blue tones. Black will however continue to symbolise a malfunctioning panel. During the user studies participants argued that it might not be necessary to see such extensive information about each of the panels at all time, but still have it available to be able to check that all of them produce as intended or to optimise. The user can furthermore check the production for the past hours by sliding the bar below the panels and choosing another time. The redesigned version is shown in figure 8.10.

Repayment

Guidelines: 3.9

Open rings getting more and more completed was developed to visualise the repayment process which can be seen in figure 8.11. There are two sorts of repayment. One financial, which can be seen as the blue ring to the left and one environmental which is represented as the green ring to the right. For more information on how the environmental repayment works the user can click on the information symbol in the upper right corner. The repayment progress is given both as a percentage and as the time left until it has been repaid.

8.3.4 Electric vehicle

This section presents four concepts on electric vehicles and charging. The concepts regard how to display the most used functions with highest priority, the monthly charging cost, information on charging and charging history.

Overview of EV

Guidelines: 2.2, 5.1

An overview of the EV was developed which can be seen in figure 8.12. The user's car is shown at the top. If the user has multiple cars the user can switch between them and the dots below indicate what car it is. The ring in the middle shows the charging. The circular version of the charging was chosen based on the symbol survey and the fact that it was suitable for showing the charge percentage in the middle and the chosen maximum charge as the white ring. The filled in ring shows the current charge. A flash symbol and the lighter blue colour used for electricity consumption is used to indicate that the car is currently charging. The button to the left with a fan symbol turns the Air Conditioner [AC] on and off. The button to the right will start the charging and stop the charging if the car is currently charging.

Monthly charging cost

Guidelines: 1.10

The user can see the accumulated cost of the current month in the upper bar and the average monthly cost in the lower bar (figure 8.13). The dashed lines show the forecast of the cost at the end of the month.

Charging information

Guidelines: 5.2, 5.3

Scheduling of charging and charging limit can be set by clicking on the blue buttons to the right in figure 7.36, and then scrolling to the desired setting in the scroll down menu that appears. The user can decide when to charge by choosing one of the options shown at the top in figure 8.14. The options are to charge when the cost is the lowest, when it is best for the environment or when it can be charged with solar power.

Charging history

Guidelines: 1.9

The charging history is shown in a diagram which can be seen in figure 8.15. There are daily, monthly and yearly views. The bars are blue if the electricity is taken from the electric grid and yellow if solar power has been used.

8.3.5 Achievements

Achievements is a concept not belonging to any of the other categories presented, therefore the idea on how to utilise achievements in the solution is presented in this section.

Guidelines: 3.6, 5.4, 5.5

Goals and achievements were added in order to create engagement and motivation (figure 8.16). The user can set new goals by clicking on the plus symbol. The trophy used to represent goals and achievements is based on the symbol survey where it was the most preferred version. The goal is written on the trophy and the progress can be followed by looking at the bar below. How much is left to reach the goal is written in more detail below the bar. The colour on the trophy is the same blue used for electricity consumption. A previous completed goal can be seen to the right and when it was completed is written above. The *Show more* arrow will take the user to more completed goals. The arrow and the *Add new goal* symbol are green to indicate that they are clickable. For bigger achievements the trophies could have a bronze, silver and gold colour to indicate how big the achievement is.

9

EVALUATION

The evaluation consisted of a user evaluation and a theoretical evaluation with personas and guidelines, which will be presented in this chapter. In the following sections the aim, procedure and result of the evaluation as well as a conclusion will be presented.

9.1 Aim

The main purpose of the evaluation phase was to evaluate the developed concepts and to ascertain that it meets the requirements and guidelines as well as to gain an understanding of its strengths and weaknesses so that it can be improved before finalising the result.

9.2 Procedure

The concepts were evaluated with users and theoretically by using the personas (*5.4 Personas*) and the guidelines (*7.2 Guidelines*). The procedure will be explained in the following sections.

9.2.1 User evaluation

The concepts presented in section *8.3 Concepts* were evaluated with six users presented in table 9.1. The evaluation was divided into two parts: firstly the users were shown the clickable prototype in *Adobe XD* and asked questions about the different attributes and about the app as a whole, whereafter they were asked to say whether they agreed or disagreed to five statements as well as assign values to a semantic differential scale.

Table 9.1. Participants of the evaluation

	Type of user	**Accommodation**	**Age span**
User 1	Website user	Rental apartment	20-30
User 2	Invoice	Detached house	50-60
User 3	Invoice	Detached house	60-70
User 4	Invoice	Rental apartment	20-30
User 5	App user	Tenant-owned apartment	20-30
User 6	Invoice	Detached house	60-70

The evaluation with User 1, 4 and 5 were conducted in person and the evaluation with User 2, 3 and 6 were conducted remotely. All users besides User 4 also participated in the first round of interviews. None of the users were shown the app on a mobile phone, but the walkthrough was conducted on a computer screen. This was because they were going to be given the same experience and evaluate the app on the same conditions. During the walkthrough they were asked to explain what they believed certain attributes meant or how they worked. Furthermore, they were immediately asked what the colours in the clock for *Current consumption* (figure 8.3) symbolised, then showed the rest of the app and asked other questions before returning to the clock and once again asked to explain what they thought the colours symbolised. This was because it was believed to have an impact on the understanding of the colours when they had seen the rest of the app. After the walkthrough they were asked to share any thoughts they had on the app and were asked some general questions on whether they would use an app like this and if they missed anything in the app.

The statements and the semantic differential scale were conducted via an online questionnaire. This was accessible for both the users in person and remotely. Both the statements and the semantic differential scale were presented to the users in Swedish, and have been translated to English when the results are presented in section *9.3.1 User evaluation*. There were five statements varying between a positive and a negative attitude. Each statement had five levels between "Completely disagree" and "Completely agree". A five level scale enabled the user to assign a neutral value by picking the one in the middle. The semantic differential scale also had five options, varying between an adjective and its antonym. The users were asked to assign a value according to how they perceived the app they had been shown.

9.2.2 Theoretical evaluation

The concept was also theoretically evaluated based on how well the solution fulfilled guidelines and how well it suited the different personas.

Persona evaluation

The four personas which had previously been created (presented in section *5.4 Personas*) were used to evaluate the concept. By taking their characteristics and needs into consideration, lists of what they would consider advantages, limitations, favourite functions and desired functions were created. Favourite and desired functions related to specific functions while advantages and limitations were more about their general impression of the concept.

Guidelines evaluation

Since the guidelines had established what functions should be included and how they should be implemented they were used to evaluate whether or not the developed concept fulfilled the criteria. Each guideline was given a grade of how well the concept fulfilled the guideline. For the guidelines regarding functionality a simple "Yes" or "No" was given, for instance the guideline "Visualise how consumption is distributed throughout the day" had been implemented in the app and therefore got assigned "Yes". For guidelines about visualisation or usability an additional grade "Somewhat" was used as these guidelines were sometimes partly fulfilled but not entirely, for example being fulfilled in some places in the app but not in others.

9.3 Results

In this section the result from the user evaluation and theoretical evaluation will be presented. The user evaluation investigated if the users understood the functions in the app concept and what their general thoughts and feelings were. It also included statement ratings where the users chose to what degree they agreed to different statements regarding the app and a semantic differential scale where the users graded how they perceived the semantic expression of the app. The result of the statement ratings and semantic differential scales are shown using the maximum, minimum and mean values. The theoretical evaluation consisted of a persona evaluation and a guidelines evaluation. The persona evaluation shows how the different persona would perceive the app according to their characteristics and needs. The guidelines evaluation show if and how well the concept fulfills the guidelines.

9.3.1 User evaluations

The evaluation session was initiated with a walkthrough of the app with occasional questions regarding the understanding of the attributes and the design. When asked what the different colours in the *Current consumption*-clock (figure 8.3) represented the first time some participants had a difficult time understanding it correctly. They guessed different electricity sources (hydro, wind, sun) or difference between day and night, while some other participants immediately understood the intended meaning. However, all participants understood the meaning of the colours in the clock after seeing the rest of the app. When asked about the clock the second time User 4 stated "*Now I understand the colours! One of them is produced and the other one is bought. And since Agneta's car was dark blue I guess the dark blue is when she charged her car*!". Furthermore, User 4 mentioned that they appreciated the colours and that it felt logical to keep the colours throughout. User 1 also mentioned that the colours contribute to a cohesive impression and stated that they would probably know how to use the app immediately. User 6 understood the colours, but were hesitant to whether the clock should spin in the way it was intended. The clock was explained as the time right now would always be at the top, and that the placement of the fades would not spin, but the hours would as time passed. User 6 suggested that it might be more intuitive if the times were set at the same place, especially as people are not used to a 24-hour clock. It was furthermore argued that it would be beneficial to include more times around the clock, and User 6 declared "*Spontaneously I thought that the time to the left would be 9 o'clock. If 13:00 is at the top, what time is it at the bottom? It's not very obvious.*". During the walkthrough of the app it was also discussed whether it would be more logical if the blue bar was placed at the other end of the bar, since that would make it easier to compare the consumption for the house besides the car consumption.

The users were asked what they thought would happen if they clicked the down-arrow below the house shown in figure 8.1. Clicking the arrow would open the more thorough illustration of the flow of electricity between the solar panels, grid, household and EV. All participants suggested that clicking the arrow would either scroll down the page or open something additional. This was perceived as intuitive by the participants. Thereafter the participants were asked whether they understood the illustration of the flow or not. This was also something all participants understood immediately and User 1 said "*Wow, I can see exactly everything! How much the solar panels produce, what is used by the car and the house, how much I buy from the grid and where it's used in the home. Yellow wave must be solar power and blue is from the grid!*" which is exactly how it was intended.

Concerning the EV page, the participants were asked if they understood the meaning of the circle for charging (shown in figure 8.12). The result showed that the majority of the participants were unsure about the meaning of the white indicator, but that most of them came to the right conclusion after some guesses. When the function had been explained, User 6 stated "*I think that is very logical now when you explained it! Especially if I somewhere had previously made the choice to only charge my EV to 80%, then I would immediately understand I think.*". User 4 on the other hand understood immediately and said "*I have done* *some research on how to take care of a battery as I've had some troubles with my computer regarding the battery…*". They all immediately however understood that the blue indicator symbolised the current charging status. It should be noted that none of the participants owned an EV, and that the result might have been otherwise if the participants had experience with how to operate the charging of an EV.

After the walkthrough of the app, the participants were asked some general questions regarding the app as a whole. User 5, who uses an app today, stated that they would absolutely use this app rather than the one they use today, and said "*I hate the app I have now! I always forget where I can find Insights and have to look for it every time…*". User 1, who uses a website to monitor their electricity consumption, also believed they would use an app like this and perceived it as intuitive and fun. The participants who only interacted with their electricity retailer via an invoice were however more hesitant. User 4 argued that it was difficult to know beforehand, but it provided much more useful information than the invoice and said "*If you only see a number of kWh, it doesn't help very much because you don't know where it comes from. If I can do something about it or if it's like the refrigerator that is always on.*". User 2 was unsure as they did not believe they would be able to affect their electricity consumption to a large extent anyway, as the largest part of the consumption was heating, especially during a cold winter. User 6 contemplated whether it would be interesting to use the app at all as they did not have solar panels. User 3 had the same line of thought, but believed they would still use the app but maybe not to the same extent as if they would have a smarter home.

Overall, the participants intuitively understood how the app was intended to be used and what the colours and attributes meant. If there were any doubts, they understood after a quick explanation. It must be stated that the evaluation mainly tested the app's guessability. However, the learnability was somewhat tested when asking about the colours of the clock both in the beginning and in the end. The result showed a high guessability and a high learnability in the areas covered.

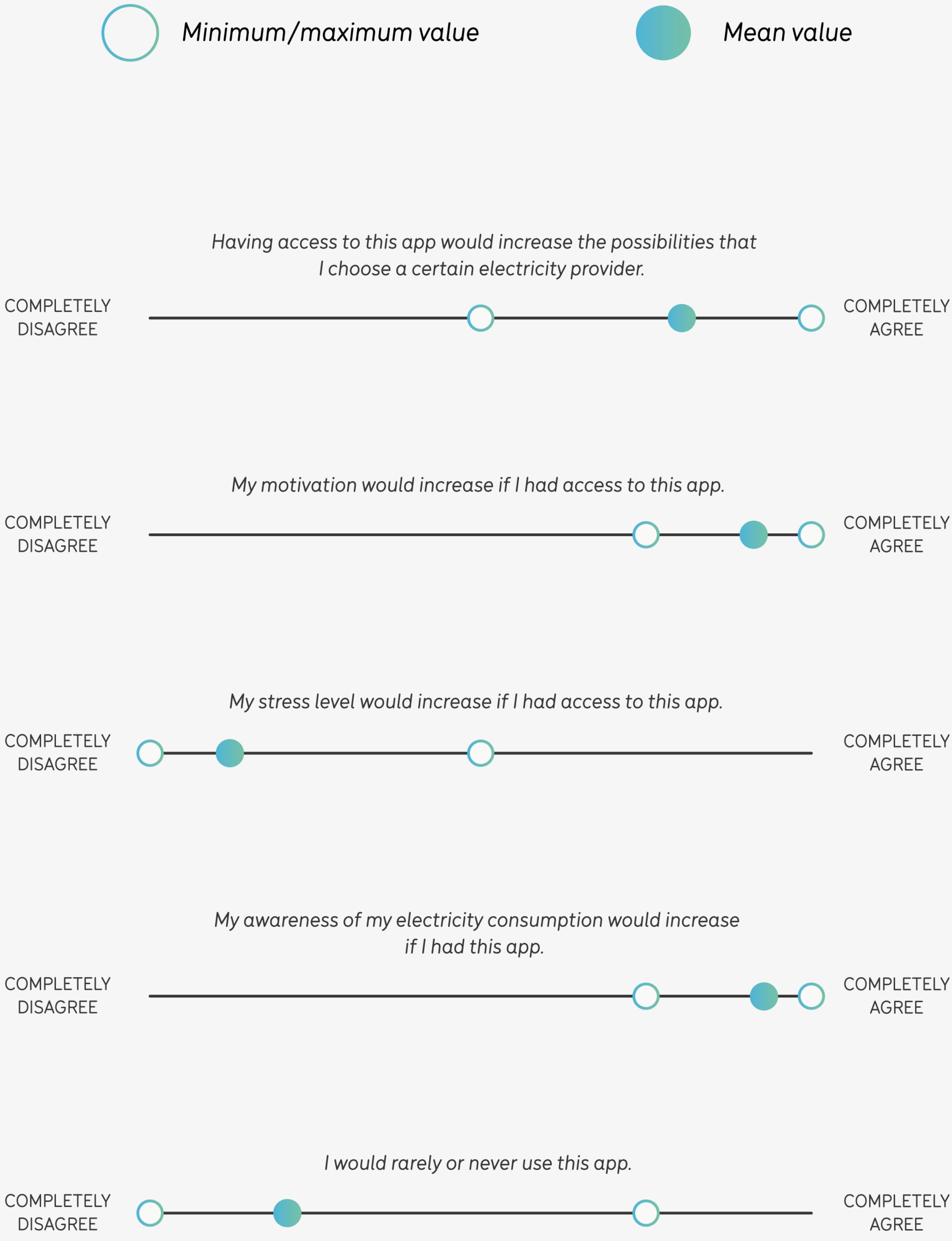


Figure 9.1. A compilation of the result of the statement ratings from the user evaluation.

Statement ratings

The result from the statement ratings were analysed and compiled in figure 9.1. The minimum, maximum and mean value was calculated. This shows how the participants answered in total, as well as within what interval the answers were distributed.

Overall, the app received positive results from the statement ratings. Having access to an app like this could affect most of the participants' choice of electricity provider, which was the intention when designing it. User 1 commented on this saying "*I would absolutely consider changing to an electricity provider offering a nice app. When I moved apartments recently I had to pick an electricity provider, and I immediately checked if they had an app for their customers.*". User 2 was however hesitant and said that "*where we live, I don't think anyone would consider another electricity provider than the local one, no matter how nice the app is..*". The distribution of the answers were also rather wide for whether they would be more stressed with this app and if they would rarely or never use it. However, the mean value for these statements are close to "Completely disagree", which is positive for these statements. Both User 1 and 2 reflected on the stressfulness of the app in the same way, and argued that maybe they would feel stressed if they performed badly and got a sad polar bear all the time. User 2 however speculated that this might only be initially when starting to use the app, and User 2 argued that on the other hand they might feel less stressed as the app would contribute to higher awareness. For the statements regarding awareness and motivation the answers are more narrowly distributed. All participants believed their motivation and awareness would increase if they had access to an app like this. It can be stated that it might be difficult for the participants to state how much they would use the app or how they would feel using it, before actually trying it out in their everyday life. However, the result from the statement ratings shows great potential.

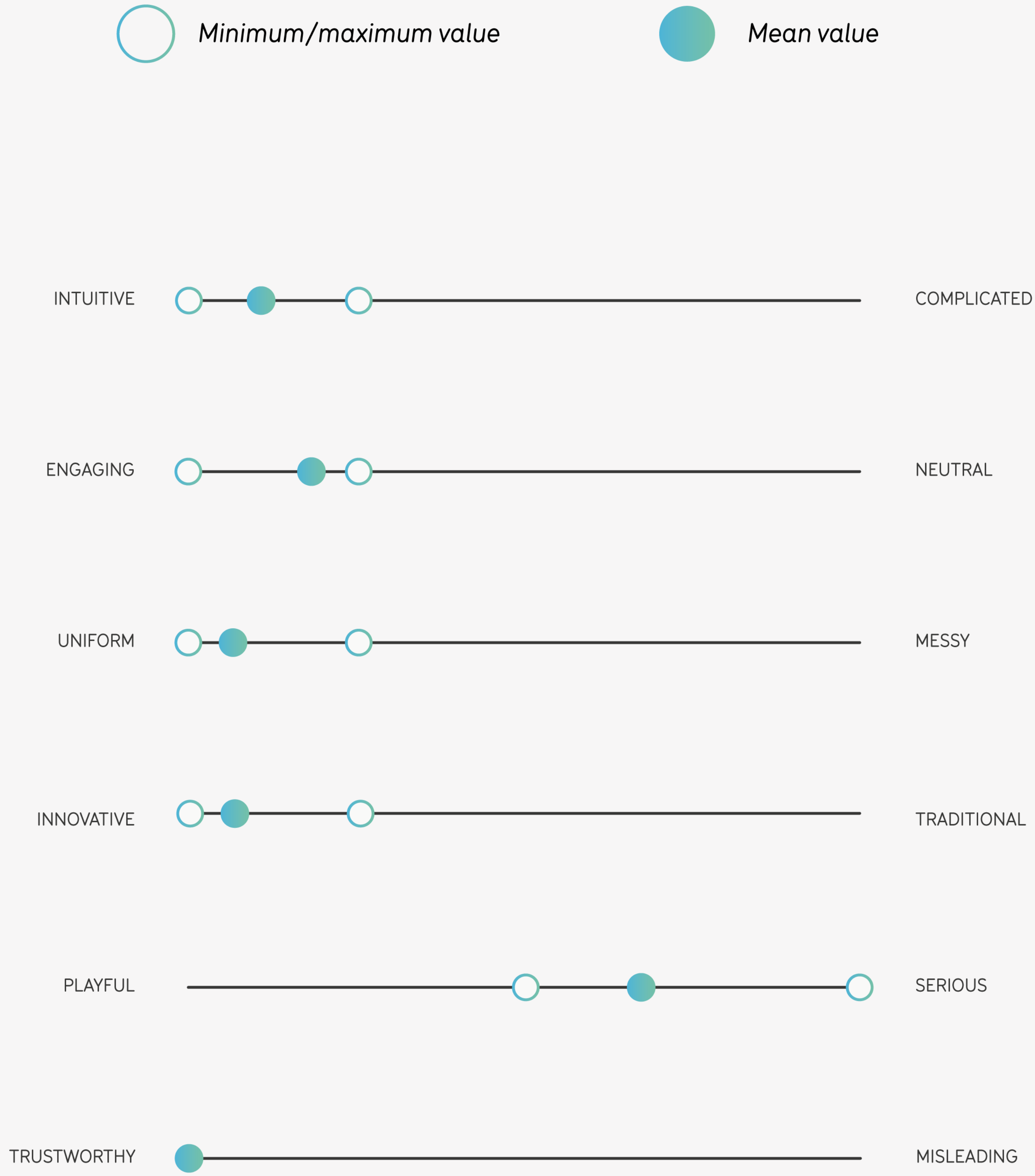


Figure 9.2. A compilation of the result of the semantic differential scale from the user evaluation.

Semantic differential scale

When the result from the semantic differential scale was analysed and compiled, the minimum, maximum and mean value was calculated to show the distribution of the answers. The result is shown in figure 9.2.

The app was considered *intuitive* by all of the participants, as the mean value is close to that end of the scale and the distribution interval is narrow. User 4 commented on the app saying "*I like that it's a mix of text and symbols, it makes it very intuitive and simple*" and User 1 highlighted that "*there is not an infinite number of things to click, it makes it intuitive*". The app was also considered *engaging*, *uniform* and *innovative* as they received similar scores as *intuitive*. It was also considered *trustworthy* by all participants as they assigned it as high as possible. The result for *playful-serious* was more spread out, with *serious* being slightly predominant. This might be because some participants wished to assign the app as both *playful* and *serious*, as they must not necessarily be contradicting, for example, User 1 said "*I would have wanted to say both. It feels serious but also playful with the pictures. Like, you could show your kid if you have done something, like 'remember when we did laundry, it looks like this'. It's a good way to show them I think.*".

The results from the semantic differential scales show positive results as the intended impressions of the app have been fulfilled.

9.3.2 Persona evaluation

The persona evaluation was conducted theoretically by discussing what the personas would consider to be the advantages and limitations of the solution, as well as what their favourite functions would be and what their desired functions would be. The results are presented below and summarised at the end of the section.

- A lot of information available
- Having all information in the same app
- Supports a sustainable lifestyle

ADVANTAGES

- Optimisation based on what is best for the environment
- Being able to set their own goals

FAVOURITE FUNCTIONS

LIMITATIONS

- Childish impression
- Struggles with trusting the app with important functions

DESIRED FUNCTIONS

- An option to send information to e-mail or export to Excel for further analysis

- Playful impression
- Easy to get a quick overview of the most important information
- Having the information in an app

ADVANTAGES

- Notifications, they are a reminder
- The polar bear makes the improvements obvious in a fun way

FAVOURITE FUNCTIONS

LIMITATIONS

- Having all the information easily accessible can be stressful
- Not obvious if your result is good or bad

DESIRED FUNCTIONS

- To be able to add friends and compete with them
- Comparing with others

ADVANTAGES

- Easy to get an overview of the most important informations
- App enables monitoring of the consumption anywhere at any time

FAVOURITE FUNCTIONS

- The polar bear makes improvements obvious
- Being able to track achievements is a good tool to engage children

LIMITATIONS

- A lot of different diagrams

DESIRED FUNCTIONS

- Being able to add smart devices and optimise from the app

ADVANTAGES

- Important economic information collected in one place
- The colours used make the message easier to understand

FAVOURITE FUNCTIONS

- Making and following progression of budgets
- Tariff information, what the upper limits are for keeping down cost

LIMITATIONS

- Childish impression
- The information appears small on the screen and is difficult to see

DESIRED FUNCTIONS

- Information about VAT, taxes etc. regarding solar panels
- Integrate prices for bought and sold electricity to be able to optimise
- Get in contact with electricity provider and solar power company via the app

Summary

The four personas have different living situations, characteristics and needs and each correspond to different types of electricity consumers encountered in this project. The *persona evaluation* shows that it is difficult to accommodate all types of electricity consumers. Users like Christer, Agneta and Bengt might perceive the design proposal as childish, but users like Linn might instead appreciate the playfulness. Similarly, users like Christer and Agneta are believed to appreciate the abundance of available information, while users like Niklas might think that the number of diagrams are a bit excessive.

It is believed that the polar bear illustration to enhance improvements will be an appreciated function by users like Linn and Niklas. For users like Bengt, Agneta and Christer the function of setting their own goal will probably be appreciated.

There are some functions that could be further explored to support the different users. It is believed that users like Christer and Agneta would benefit from an option to export the data to, for example, Excel for further analysis. Users like Niklas might desire options of adding and controlling smart home devices from within the app. Users like Bengt might desire more extensive information to be able to further optimise, as well as getting in contact with not only the electricity retailer but also the solar panel retailer from the app. Users like Linn are motivated by social motives and might thus miss being able to compare to others, or being able to add friends to compare with their consumption. These are all functions that could be included in further exploration and development.

9.3.3 Guidelines evaluation

In this section a summary of the result from the guideline evaluation will be presented. For the complete evaluation see Appendix C. Each guideline has been assigned a prioritisation level of how important they are, where "1" means they are crucial, "2" means they are desirable and "3" means they are out of scope of this thesis but important for future development. The result showed that the concept generally fulfilled the important guidelines well. Most of the guidelines assigned a prioritisation level of 1 or 2 had been graded with a "Yes" for complete fulfilment. The most critical exception was the guideline:

- *4.4: Provide information on how the price of electricity varies over time (1)*
  This guideline was assigned prioritisation "1" but had not been fulfilled. This will need to be addressed before the final design.

There were also some guidelines regarding visualisation and usability with prioritisation "1" or "2" that had been graded with somewhat fulfilled. These were:

- *8.1: When different measurements are visualised in the same diagram, use different types of charts to increase clarity (2)*
  This has been fulfilled in for example the monthly and yearly view of the solar production diagrams, where the electricity consumption was represented by bars while the solar production was visualised as a line. It was however not fulfilled in the daily view where both production and consumption were visualised by lines. This deviation from the guideline was made because line diagrams better show

continuous changes over the day.

- *8.9: Use turquoise for clickable and/or activated options (2)*
  The turquoise colour had been used in the home screen and in insights, but in the page for solar panels orange colour are have been used and in the page for EV dark blue has been used. This was decided as it makes the theme of these pages more cohesive.

- *9.6: Make it obvious what attributes are clickable (1)*
  For the most part this is fulfilled but it may not be obvious that the user can click on individual solar panels in order to get more information about those solar panels.

The guidelines with prioritisation level 3 had not been fulfilled but this was expected since they were out of scope and had therefore not been focused on.

9.4 Conclusions

Based on the feedback and result from the evaluation, it can be concluded that the concepts to a large degree fulfils the needs of users and meet the majority of the guidelines. There were however some changes that were decided upon.

The hours in the current consumption clock will get fixed positions

The clock showing current consumption (figure 8.3) will be modified so that the hours are set in fixed positions and the current time moves around the clock, instead of the current time always pointing upwards. There will also be four hours visible, 00:00, 06:00, 12:00 and 18:00, instead of only the current time. These changes are meant to make the clock easier to understand and to facilitate for the user to quickly connect specific consumption bars to specific hours.

The diagrams will be made more readable

It was found that values on the x-axis in the diagrams were difficult to see. It was therefore decided to make them larger. In order to not make the text too crowded some of the text will be removed, for example not writing out every date of the month. The months will furthermore be written with only the first letter instead of spelling out the whole month in order to save space.

Price variations over the day will be included

It was noticed that the guideline "*Provide information on how the price of electricity varies over time*" had not been fulfilled even though it had been assigned the most important prioritisation level. The price variations will be included in the daily consumption diagram.

EV charging will be moved to the top of the consumption bar

The dark blue lines showing how much of the consumption was used to charge the EV (figure 8.3 and 8.4) will be moved from the bottom of the bar to the top of the bar. This will make it easier to compare the remaining household consumption, not used for the EV, with the other bars as they are on the same level.

FINAL SOLUTION

10

Based on the feedback and result from the *evaluation*, the concepts and the digital prototype were refined and the final design proposal was developed. This chapter first presents an overview of the app with its functions, colours and fonts, thereafter each page will be presented thoroughly.

10.1 Overview

The final design of the mobile application is to certain extent inspired by certain elements of the current design of Eliq's app. When redesigning the app, focus has been on what should be altered and added, and what is relevant to meet the aim and answer the research questions of the project. This means that the home screen for example, will probably include more elements than what is presented here, for example *Smart Thermostat* and *Bill information* that have been considered out of scope for this project. Furthermore, the information found under *Account* has been entirely out of scope, except for adding *Achievements*. Figure 10.1 shows a tree of the functions available in the app, and how they are connected.

10.1.1 Colours and fonts

The most important colours used throughout the final design is presented in figure 10.2. Figure 10.2 also states what fonts have been used throughout the design. The background is a light grey colour to keep the overall expression calm and neutral, but still be slightly contrasting to the white used on the cards occurring throughout the app. Most graphics in the design solution are bright colours with a slight fade, and the corresponding text has a similar colour without the fade. The HEX-codes for each end of the fade are stated in figure 10.2, as well as the text-colours used. Solar power has two colours related to it. This is because the orange one is required to increase the contrast with the white text used. The yellow however is used in combination with blue in the diagrams, as blue and orange can be problematic for colour blind people.

The typeface used throughout the design solution is *Menco*. Different fonts of *Menco* have thus been utilised for different purposes. *Menco Bold* is used to highlight important information. When *Menco Bold* is used, it is often in a certain colour corresponding to the information delivered. *Menco Medium* is mainly used for headlines and for common texts, but also to highlight what month or day it currently is in the diagrams. *Menco Light Italic* is used for slightly longer bodies of text and often in combination with bolder fonts to highlight the most important information.

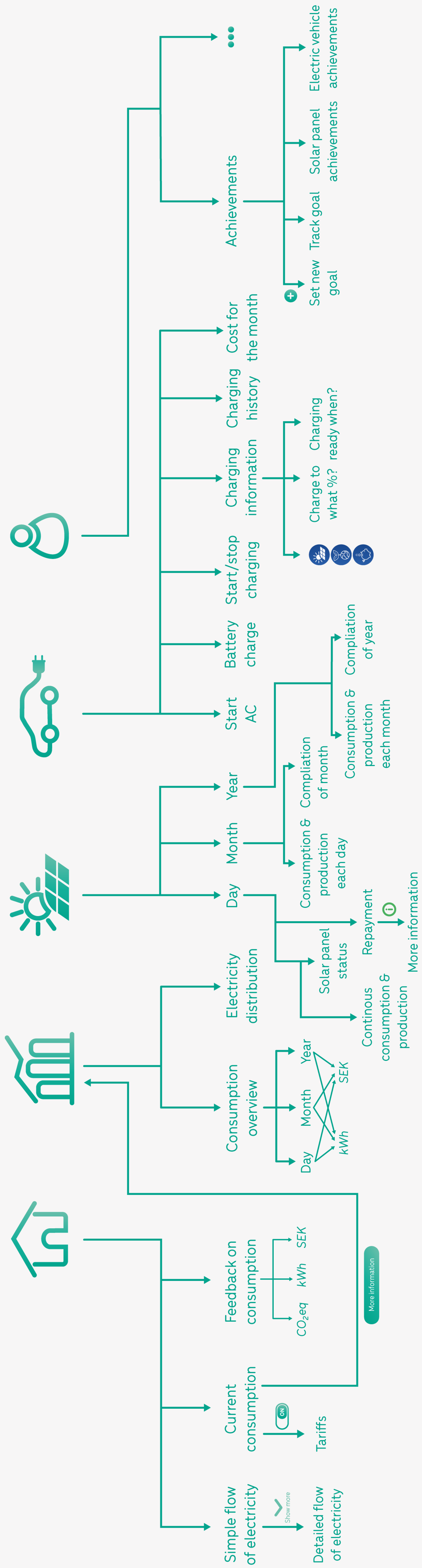


Figure 10.1. Tree of functions.

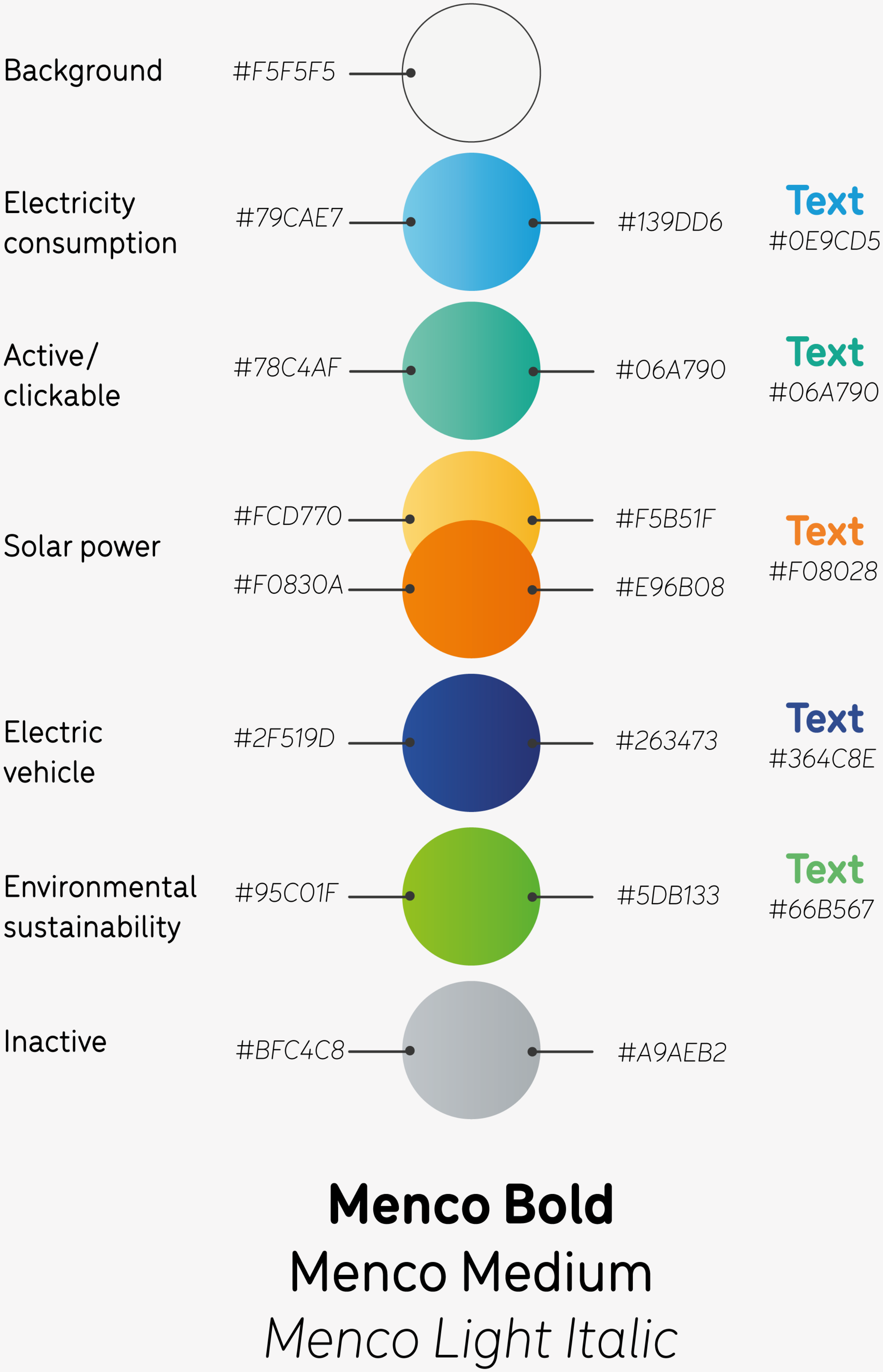


Figure 10.2. Colours and fonts used in the final solution.

10.1.2 Bottom menu

The bottom menu which can be seen in figure 10.3, was added in order for the user to be able to easily navigate in the app and will take the user to the most important pages. The symbols for solar panels and EV are the ones decided upon from the symbol survey. The home, insights and account symbols are the same as or inspired by the symbols used in Eliq's current demo app. The page which is currently open is indicated by the turquoise colour of the symbol. If the user does not have solar panels or EV these symbols will not be part of the menu. The bottom menu will be visible at all times and in addition to that there will be a back arrow in the upper left corner when the user enters secondary pages from the main pages, so that the user can choose to only take one step back.

Figure 10.3. The bottom menu if the user has solar panels and an EV.

10.2 Home screen

When the user signs in to the app, they will reach the home screen. The home screen contains the most important information: how electricity is currently flowing, how much electricity has been consumed the last 24 hours divided over the hours and how this month compares to the same month the previous year.

10.2.1 Flow of electricity

At the top of the home screen a 3D-illustration of a house quickly shows the user how energy flows between the sun, the grid, the house and the EV (figure 10.4). This illustration will adapt according to what the user has (i.e. EV, solar panels) and furthermore show an apartment building if the user lives in an apartment, examples of this are shown in figure 10.6 and 10.7. The yellow rays symbolise solar power and the blue rays symbolise power from the grid. If surplus production is being sold to the grid, a yellow ray would appear between the house and the grid. No numbers or extensive information is included in the illustration of the house, to avoid cluttering the view, but this information is instead reached by clicking the down-arrow below the house. During the evaluation of flow of electricity in section 6.3 it was appreciated to be able to decide for oneself how much information to display. In the *evaluation phase* the house received positive reactions, and the version presented in section 8.3 has thus not been altered. The house illustration is believed to contribute to a playful impression, and useful elements have now been added.

If the user clicks the arrow below the house, the house will shrink and more extensive information will appear (shown in figure 10.5). In the evaluation the participants understood that additional information would appear if the arrow was clicked. However, a "Show more"-text has been added to further enhance the understanding of the meaning of the arrow. The orange circle in the top left corner shows how much the solar panels are producing at this moment, and the yellow rays are showing where that electricity is being used. If the surplus is sold to the grid, a yellow ray would appear between the top two circles. The top right pie chart displays the energy mix for the household that is being purchased from the grid. The additional text above the chart explains the emissions the current energy mix is emitting. The bottom left pie chart shows the current electricity distribution in the household with a number of larger categories, as well as the power that is being used at that moment. In figure 10.5 the household uses electricity from both the solar panels and the grid. Lastly, the bottom right circle displays the charging of the EV, how much it is currently consuming and where the electricity is derived from. The participants in the evaluation all understood the meaning of the flow and expressed appreciation, the version presented in section 8.3 has thus not been changed. In the distribution shown in figure 10.5, the household has both an EV and solar panels. If this was not the case, only the two pie charts would be visible, but still display useful information on energy mix and distribution in the home.

10.2.2 Current consumption

Below the flow of electricity the user will have access to an overview of the current consumption and the consumption of the last 24 hours divided by hours, shown in figure 10.8. The design of the final version is similar to the one presented in section 8.3 but with some changes to its functions. In the center of the circle the total consumption for the last 24 hours are displayed, and the bars placed around the middle symbolise consumption per hour and use colours to display where the electricity is derived from. In the previous version it was intended that the current time would always be at the top. This has however been revised as a result of the feedback during the evaluation. It was perceived as confounding that the clock was not fixed. It was also stated that it would be easier to track back in time if a few more times would be included, especially as it is a 24-hours clock and not a 12-hours clock which one is used to. The clock has therefore been redesigned and the final design of the clock includes the times 00:00, 06:00, 12:00 and 18:00 at each quarter of the clock. In the new version, for example 12:00 will be fixed at the top, and the current time will spin as time passes.

The colours have been retained in the final design. They were perceived as logical and it was appreciated that the same colours reappeared throughout the entire app. The light blue colour thus symbolises that the electricity used has been purchased from the electric grid, the yellow symbolises that solar power has been used and the dark blue, thinner bars display when the EV has been charged. This furthermore also shows what type of electricity has been used to charge the EV. However, the placement of the dark blue bars for EV have been changed according to what was discussed in *9.3.1 User evaluations*. In the final design the blue bar is thus placed at the outer edge of the other bars. This will make it easier for the user to compare the household consumption for each hour with bars not including EV charging. Also, the dark blue bars for EV have been given square edges instead of rounded as in the previous versions. If the user does not have EV or solar panels, all bars would be light blue.

Power tariffs have been retained from the previous version. Power tariffs can be implemented in various ways, but the final design proposal has been inspired from what is presented in section *2.1.4 Tariffs*. The idea is that the consumption of electricity from the grid shall not exceed the dashed line for tariffs, in order to keep the monthly fee below a certain amount, except during the night when the used effect is of less importance. The user can however choose to hide the dashed lines for tariffs.

Figure 10.4. Homescreen - the house, including solar panels and EV.

Figure 10.5. Homescreen - the flow of electricity.

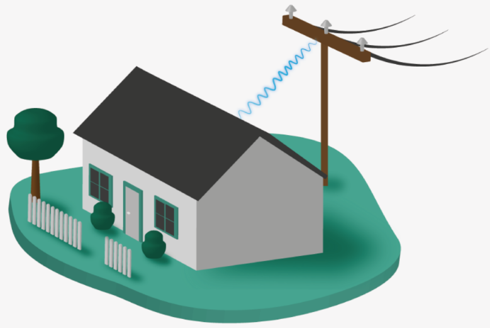


Figure 10.6. Alternative version of the house, without solar panels and EV.

Figure 10.7. Alternative version of the house, apartment.

Figure 10.8. Homescreen - Current consumption.

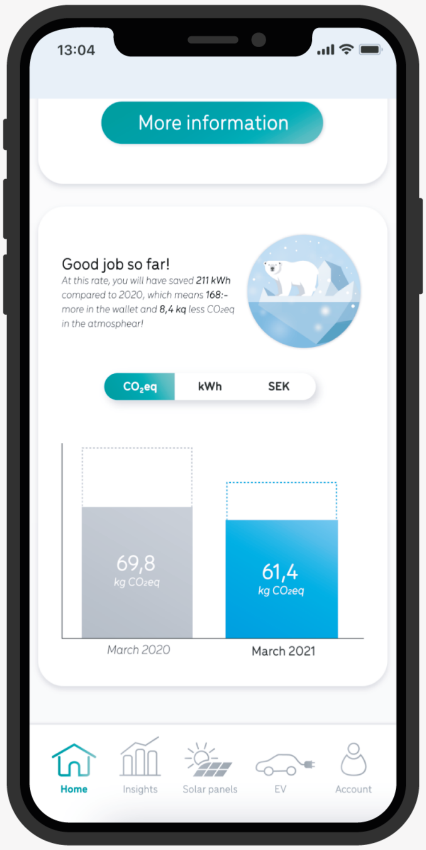


Figure 10.9. Homescreen - feedback on consumption with help from polar bear illustration, happy version.

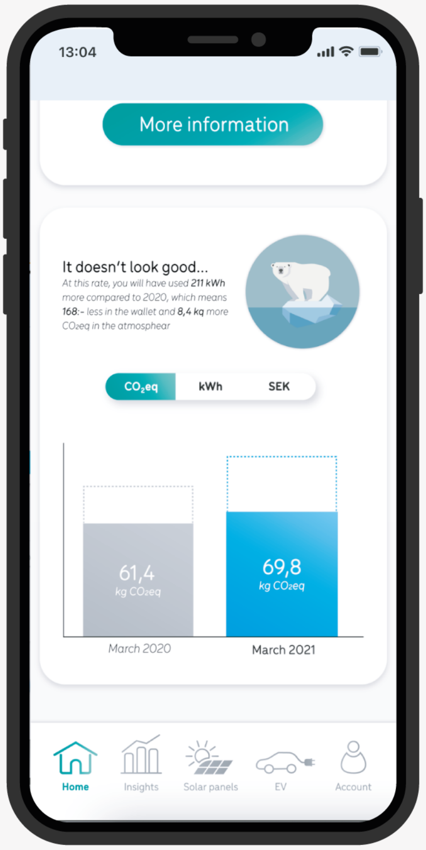


Figure 10.10. Homescreen - feed-back on consumption with help from polar bear illustration, sad version.

10.2.3 Feedback with polar bear

The illustration of the polar bear will be displayed on the home screen so the user will encounter it continuously. The polar bear will shift between healthy and thriving in a snowy environment (figure 10.9) and sad and disappointed on a shrunken iceberg (figure 10.10), with a neutral option in between. The polar bear will be displayed in combination with a text informing the user of the consequences if they continue their consumption at the same rate the current month. The text is based on calculations on previous behaviour compared to the behaviour this month.

Below the text and the polar bear the consumption for the current month is displayed in a blue bar. The dashed blue line shows the forecast for the rest of the month. The grey bar to the left of the blue bar shows the consumption thus far during the same month last year. The grey dashed line shows the rest of the month last year. This enables continuous comparison throughout the entire month. Furthermore the user will be able to turn the development around if they receive a sad polar bear. They can decrease their consumption and thus change the forecast and get a happier polar bear. The consumption can be displayed in three different units: CO_2eq, kWh or SEK.

10.3 Insights

The second item in the bottom menu is the *Insights*. The user will also be able to reach *Insights* by clicking *More information* in *Current consumption* (shown in figure 10.8). Information focusing on consumption will be available here, including consumption statistics and the electricity distribution in the home. Insights will be available to all users, independent if they have EV and solar panels or not.

10.3.1 Consumption statistics

The consumption statistics were appreciated by the users in the evaluation, and has therefore to a large extent been retained. Small changes have however been done compared to what is presented in section 8.3. Throughout all views, the times, dates and months on the x-axises in the diagrams have been reassessed and made larger but also fewer. This is to increase visual clarity when displayed on a mobile screen.

The Day-view has similar information as the *Current consumption* (figure 10.8), but in a horizontal format (figure 10.11). Opposed to the circular version used in *Current consumption*, the horizontal version does not show the last 24 hours, but the current day. The forecast is shown as dashed lines. This view also includes power tariffs that can be turned off if the user does not want to display the lines at all times. The light blue bars symbolises the electricity purchased from the grid, and the yellow bars the solar power used. The thinner, dark blue bars inside the other bars symbolise when the EV has been charged and how much electricity it has consumed. Compared to the version presented in section 8.3 the EV-bars have been moved to the upper edge of the bars to facilitate the comparison with the rest of the household. Furthermore, the user can switch between displaying the consumption in kWh or SEK. As is shown in figure 10.12, in the day-view the cost-diagram can be at zero at times when all electricity used is solar power. As discussed in *9.3.3 Guidelines evaluation* the variations of the price of electricity over the hours had not been included. To fulfill this guideline, the price of electricity has been added in the Day-view diagram. This is the grey area behind the price-line in figure 10.12.

The monthly view shows the consumption day by day, with the bars being divided into blue and yellow parts showing to what extent electricity has been purchased from the grid and utilised from solar panels respectively (figure 10.13). The dashed lines are a forecast, which is calculated based on previous use patterns, weather forecast and other factors affecting the consumption. The user can choose to display the consumption in kWh or SEK (figure 10.14) in this view as well. The yearly view works in a similar way, but displays consumption month by month instead (figure 10.15).

10.3.2 Electricity distribution in the home

Under Day -, Month - and Year view respectively there will be a pie chart showing the household distribution over said period of time. Under Day-view for example, the consumption in kWh over the day will be displayed in the middle, with the distribution over a number of categories around. The consumption derived from charging the EV has been separated and displayed underneath. Month-view shows the consumption and distribution for the month, and Year-view the consumption and distribution for the year. This would enhance the understanding of how the consumption is divided between different parts of the home. Figure 10.16 shows how this could look like for a month. If the user has chosen to display the diagram in the unit SEK, the unit for the electricity distribution will also change to cost-focused.

Figure 10.11. Insights - consumption statistics: Day, kWh.

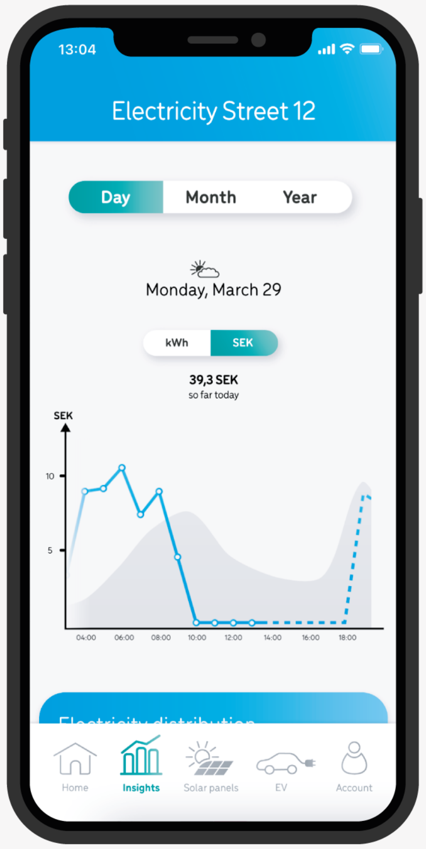


Figure 10.12. Insights - consumption statistics: Day, SEK.

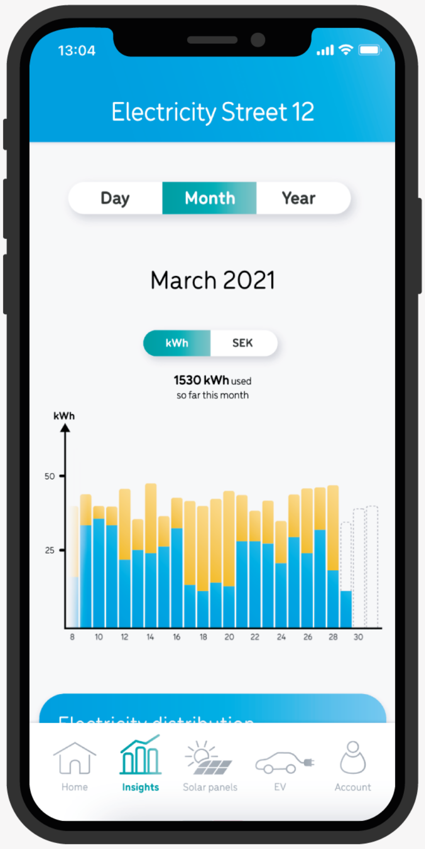


Figure 10.13. Insights - consumption statistics: Month, kWh.

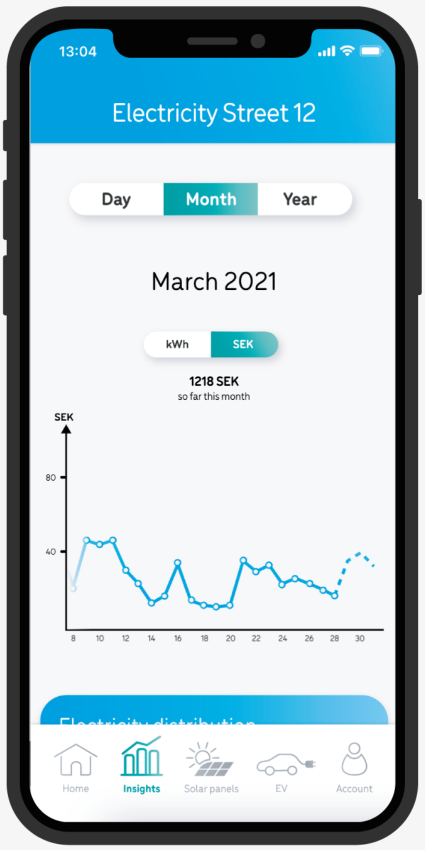


Figure 10.14. Insights - consumption statistics: Month, SEK.

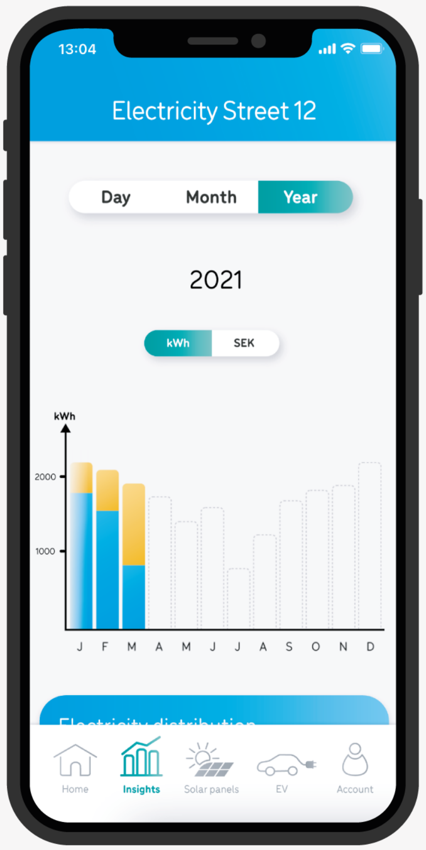


Figure 10.15. Insights - consumption statistics: Year, kWh.

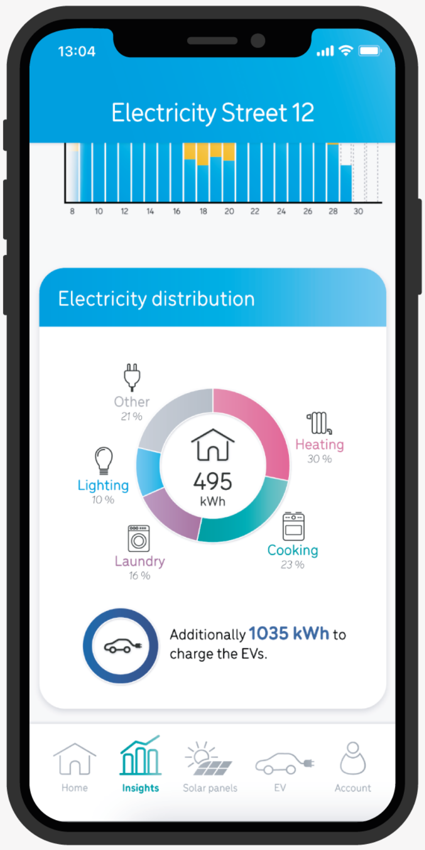


Figure 10.16. Insights - Electricity distribution for a month.

10.4 Solar panels

If the user has solar panels installed this page will contain information related to those solar panels. The user can see the production and consumption together, a compilation of the production, consumption and their net value, information on individual solar panels and information on the financial and environmental repayment processes.

10.4.1 Production and consumption diagrams

To visualise both production and consumption together over a time period was found to be a desired function. The diagrams show this information in daily, monthly and yearly views. The daily view is a line diagram with a blue line for consumption and a yellow line for production. The x-axis shows hours of the day and y-axis shows the power [Watt] produced and consumed at different times. The black vertical line shows the current time. A weather symbol indicating the weather of the day was added next to the date since the weather is an important factor for the level of production. The daily view is shown in figure 10.17. In the monthly and yearly views the consumption is represented by blue bars and the production is represented as a yellow line with dots for each day in the monthly view or each month in the yearly view. The monthly view is shown in figure 10.18 and the yearly view in figure 10.19. The y-axis shows the energy [kWh] used and produced over the time period. Participants had expressed that if possible it would be good to use different types of charts for different things if they were in the same diagram. The line diagram was however kept for the daily view since it better visualises continuous change. Dotted lines show forecasts. Based on feedback on previous versions it was also decided to keep the diagrams simple and to put other information such as the net value somewhere else. It was however decided to make the dates underneath the diagram larger and not include every date. This was conducted in order to increase visibility.

10.4.2 Compilation

To get an overview of the production and consumption and net value a compilation shown in the monthly and yearly views was added (figure 10.19). As discussed in section 6.3 it was found that users would like to see bought, sold and net energy. The net energy was considered especially important if it was not included in the production and consumption diagrams. The compilation shows the total production and consumption so far of the current month or year, how much is bought and sold and also net value in monetary terms with a minus indicating loss and a plus indicating profit. The texts in the information table are the same colours as the corresponding graphs except for the yellow taking a darker more orange tone for visual clarity. Lastly, the compilation also informs the user of how much of the electricity used comes from the owner's solar panels. This is visualised in a Venn diagram where the orange circle represents production, the blue circle represents consumption and the green in between represents the solar powered electricity consumption. The Venn diagram also gives an easy overview of how the scale of production and consumption compare to each other. During the evaluation it was apparent that the users appreciated that the Venn-diagram was not a still-picture, but will adjust accordingly.

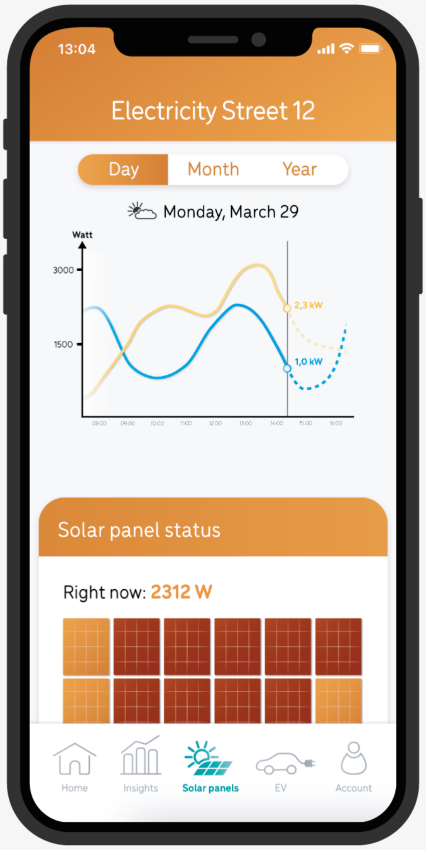


Figure 10.17. Solar panels - production and consumption diagram: Day.

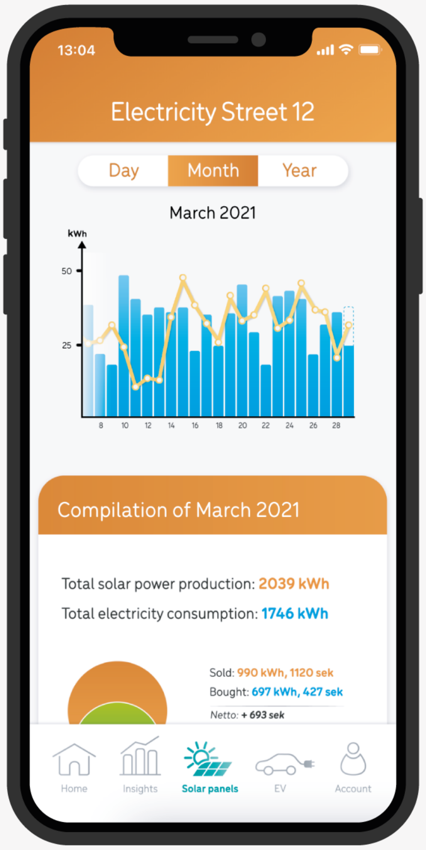


Figure 10.18. Solar panels - production and consumption diagram: Month.

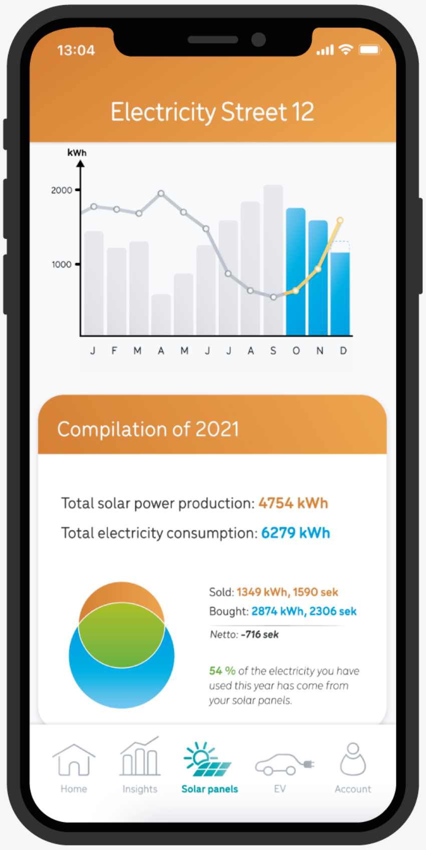


Figure 10.19. Solar panels - production and consumption diagram: Year, and compilation of 2021.

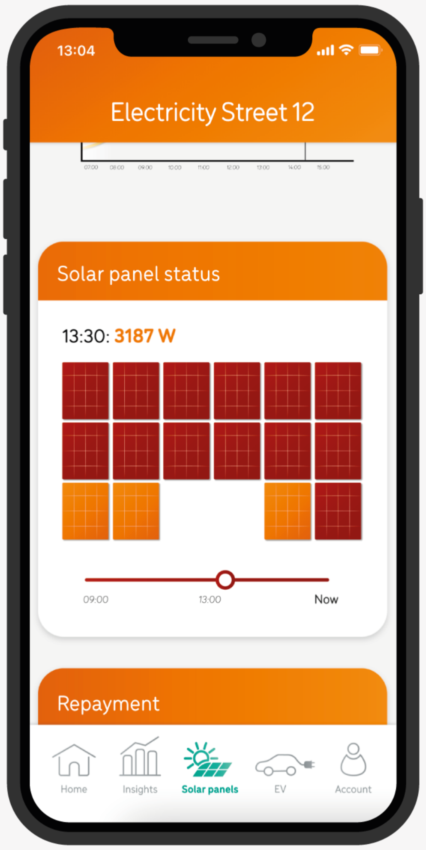


Figure 10.20. Solar panels - Solar panel status.

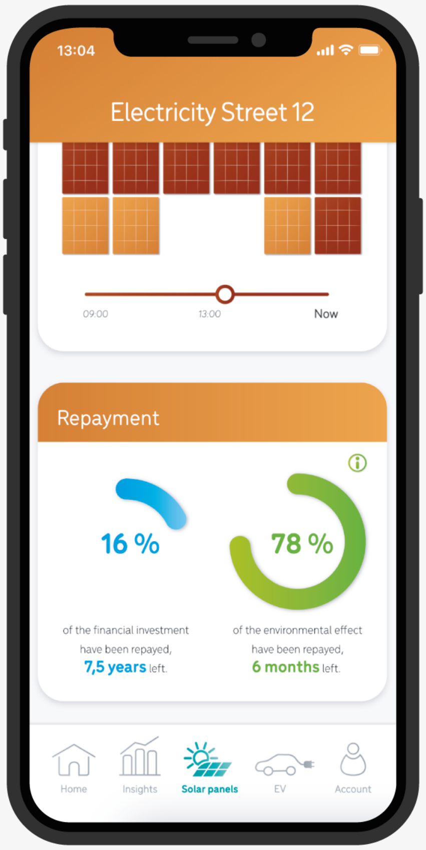


Figure 10.21. Solar panels - Repayment.

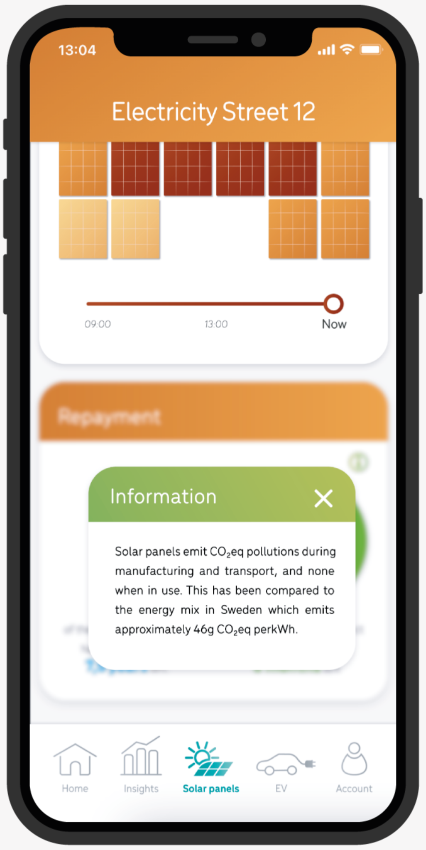


Figure 10.22. Solar panels - Repayment, explanation box for environmental repayment.

10.4.3 Solar panel status

To provide the user with a more in depth view of the production from their solar power facility the production from individual panels is included (figure 10.20). During the evaluation with users in section 6.3 it was found that the participants appreciated that the panels varied in colour based on their production, as it facilitated an easy and quick overview. They interpreted a dark colour as higher production and black colour as the panel being broken. The colours used here are red, orange and yellow where red indicates higher production and yellow lower production (the yellow colour is visible in figure 10.22). Participants expressed that they prefer warmer colours as it has stronger connection to solar radiation. Black is used to symbolise a faulty panel and the user will be notified when a panel turns black. More detailed information on each solar panel can be reached if the user clicks on the panel. Users expressed that they thought extensive information written on the solar panels constantly visible would be redundant and preferred a more clean and simple look. The user can furthermore check the production for the past hours by sliding the bar below the panels and choosing another time.

10.4.4 Repayment

In order for the user to be able to see the repayment process this information was added and visualised as open rings moving further towards completion as the repayment process continues (figure 10.21). There are two sorts of repayment. One financial, which can be seen as the blue ring to the left, where the user's initial financial investment of installing the solar panels will be repaid by saving on the electricity cost and the profit from selling surplus production. The financial repayment time is approximately 10-14 years. The green ring to the right symbolises environmental repayment. The solar panels cause CO_2 emissions during manufacturing and transportation but will not emit any pollution during use, which saves the pollution which would otherwise have been emitted by using energy mix from the electric grid. The environmental repayment time is approximately 1 year. For more information of how the environmental repayment works the user can click on the information symbol in the upper right corner. By doing so an information box will appear (figure 10.22). The repayment progressions is given both as a percentage and as the time left until it has been repaid.

10.5 Electric vehicle

If the user has an EV this page will contain the most important EV functions. Here the user can see the current charge and charging limit, turn the AC on and off, start and stop the charging, schedule the charging, set a charging limit, see the charging history and the current month's charging cost.

10.5.1 Overview

Since people can have more than one EV and these EV's have different information and need to be controlled separately, the car to which the following information belongs to is shown at the top in figure 10.23 and 10.24. The cars can be switched between by swiping horizontally on the car. The blue and white dots below indicate how many cars there are and which one is shown for the moment. If there is only one car there will be no dots.

The charging ring in the middle visualises the charging. The filled in colour ring shows the current charge and the white ring indicates to what degree the battery should be charged to. It was found both in the literary studies and the empirical studies that the EV should not be charged to 100 % since it is harmful for the batteries. The number in the middle of the ring shows the percentage of the charge. In the evaluation it was found that participants understood the filled in ring immediately and either understood the white ring immediately too or came to the right conclusion after some guesses. It was found to be easy and logical after being explained. In figure 10.24 the lighter blue colour used for electricity consumption in combination with white lines towards the end of the ring indicates that the car is currently charging. If the EV was to be charged from solar power, the ring would be orange.

The button to the left with a fan symbol turns the AC on and off as that was identified as a desirable function from the interviews. In figure 10.24 the colour indicates that the AC is turned on. The AC will use the last temperature setting used in the car. The desired temperature is likely to be the same over a period, for example colder in the summer and warmer in the winter. The button to the right will start the charging as can be seen in figure 10.23 and stop the charging if the car is currently charging as can be seen in figure 10.24.

10.5.2 Charging information

During the benchmarking and during the user studies several desired functions were identified. Owners of EV's want to be able to schedule the charging and to decide how much to charge. This is convenient, better for the battery and enables the user to not put unnecessary strain on the electric grid. The scheduling and the maximum charge can be changed by clicking on the blue buttons to the left in figure 10.25. After clicking, a scroll menu is opened and the user can scroll to the desired setting. The options for the scheduling are in intervals of half an hour and the maximum charge is in intervals of 5 %. When a new maximum charge has been set the white charging ring will be updated accordingly.

There may be more time available than necessary to charge the car to the desired settings which opens the question of when in that time span the car should actually be charged. The user has options which can be seen in the three circular buttons in figure 10.25. The user can choose to charge the car when the cost is the lowest, when the emissions are the lowest or in the case where the user owns solar panels when the sun is up from solar power. If the user has chosen to charge with solar power but only has the EV connected to the charger when the sun is not up, or the solar power is not enough to charge completely, the car will be charged according to the previous setting i.e. when the cost or the emissions are the lowest.

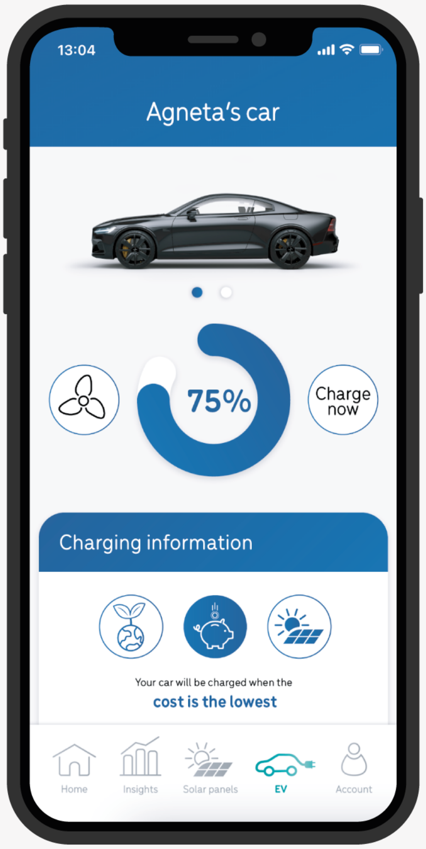


Figure 10.23. EV - overview car 1: not charging.

Figure 10.24. EV - overview car 2, charging, AC is on.

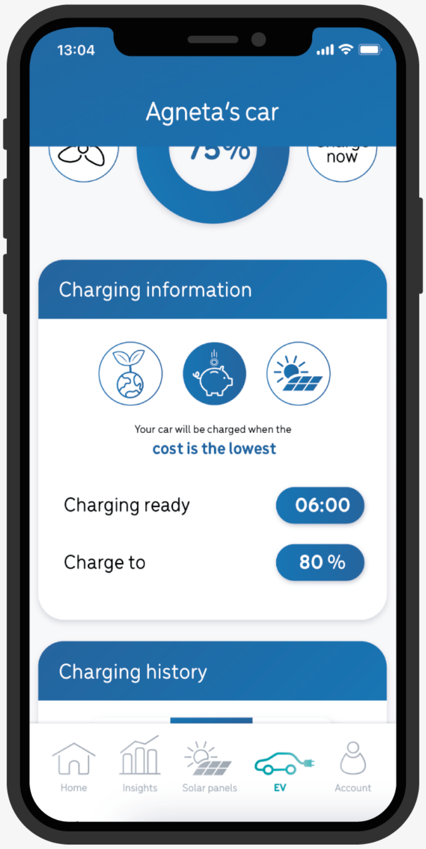


Figure 10.25. EV - Charging information.

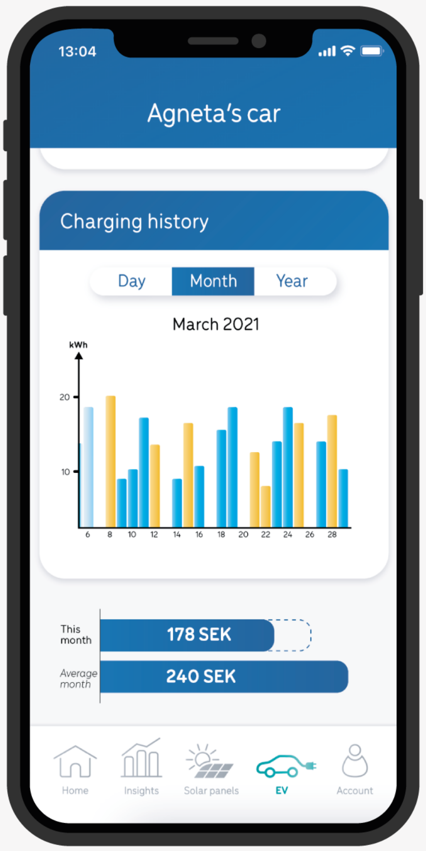


Figure 10.26. EV - charging history: Month, and monthly charging cost.

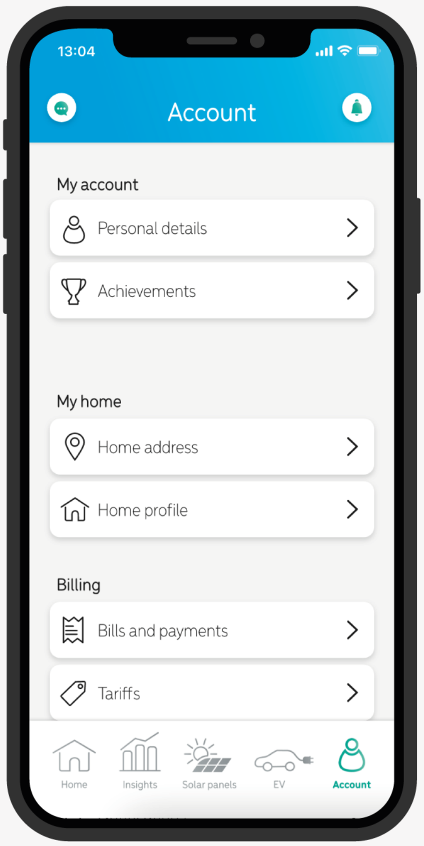


Figure 10.27. Account.

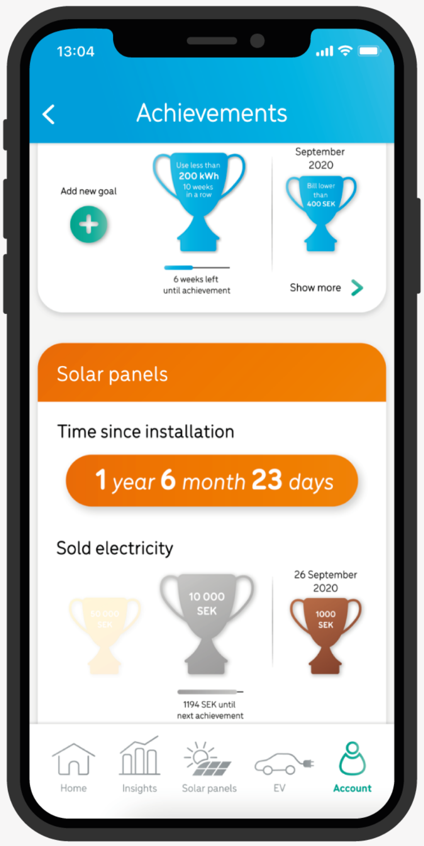


Figure 10.28. Account - achievements. Set personal goal and Solar panels achievements.

10.5.3 Charging history

In order for the user to be able to see how much electricity their EV has consumed over different time periods the charging history has been collected and presented in a diagram, figure 10.26. It was found that users want to be able to see their EV electricity consumption separately from the rest of the household consumption. There are both daily, monthly and yearly views. In the daily view the bars represent hours, in the monthly view they represent days (this view is the view in figure 10.26) and in the yearly view they represent months. The y-axis shows the consumption in kWh. If the colour of the bars are blue it means the electricity comes from the electric grid and if they are yellow it means the EV is charged with production from solar panels.

10.5.4 Monthly charging cost

In order for the users to be able to see an overview of the charging cost the monthly cost has been compiled into a horizontal bar chart, shown at the bottom of figure 10.26. The top bar shows the cost so far in the current month and the dashed outline shows the forecast of the cost at the end of the month. The bar below shows the cost of an average month which makes it easier to make comparisons. The cost is written on the bars.

10.6 Account

The last page is the account page which contains functions relating to the following categories; *My account*, *My home*, *Billing*, *Settings* and a logout function (figure 10.27). The functions in the account page have mainly been out of scope for this project and the account page has therefore for the most part kept the same design and functions as Eliq's demo app. These functions have not been expanded or prototyped further and the intention is to let them work the same as the current solution. One major addition however, is *Achievements* which have been added under *My account.*

10.6.1 Achievements

In order to create engagement and motivate people to decrease consumption, goals and achievements have been added which can be seen in figure 10.28. The user can set their own goals by clicking on the plus symbol. The user can set goals freely but will also be recommended goals based on previous behaviour. The symbol used to represent goals and achievements is a trophy based on the symbol survey, where the trophy was the most preferred version. The idea to use different colours for different kinds of goals and achievements has also been implemented. When a goal has been set, such as "Use less than 200 kWh 10 weeks in a row" like in the example, it will be written on the trophy. The progress of the goal can be followed by looking at the bar below the trophy and how much is left to reach the goal is written in more detail below the bar. The colour on the trophy is the same blue used for electricity consumption (top of figure 10.28). A previous completed goal can be seen to the right and when it was completed is written above. If the user wants to see more completed goals the user can click on the *Show more* arrow. The arrow and the *Add new goal* symbol are green to indicate that they are clickable. A vertical line divides the current goal from the completed goal.

Bigger achievements relating to solar power and electric fuel savings, are also represented with trophies but with the colours bronze, silver and gold to indicate how big the achievements are. The solar panels achievements are shown at the bottom of figure 10.28. Bronze achievements are the easiest and are the first ones to be completed, followed silver and lastly gold. Every level must be completed before the next level is unlocked. The locked trophies are masked in a lighter colour. Changes from the previous version evaluated with users (section 8.3) are that the trophy for the current achievement is bigger than the rest, that the bar below the trophy has the same colour as the trophy and not the type of achievement i.e. yellow for solar panels, that a vertical line dividing the completed achievements from the rest has been added in the same way as for the goals, that time since installation of solar panels have been added and that achievements relating to the EV has been added.

For the solar panels the achievements relate to the amount of electricity sold. A solar panel installation of 5 kW in Sweden will generate around 3750 SEK per year on sold surplus production (Ahrlberg, 2021). The achievements are to sell electricity for:

- Bronze: 1000 SEK (takes around 3 months)
- Silver: 10 000 SEK (takes around 2,5 years)
- Gold: 50 000 SEK (takes around 13 years)

Achievements relating to the EV have been added since the concept development stage (section 8.3). For the electric fuel savings of the EV the achievements have been categorised into *Economy* and *Sustainability*. The economic achievements relate to cost savings from using electricity to drive the car instead of fossil. In order to set the different levels the cost for driving an EV versus a gasoline car was calculated. The average distance a private car is driven in Sweden per year is approximately 12 000 km (Trafikanalys, 2020). To drive an electric car costs approximately 2,6 SEK/10 km (Wästgöta Finans, 2020). This means that the electricity for an average EV costs 3100 SEK/year. To get the fuel consumption for a gasoline car the average consumption of the middle sized cars in a test done by Teknikens Värld (Wedberg, 2015) was used. The average was 0,68 l/10 km. If the car is driven the average 12 000 km it corresponds to 816 l/year. The cost for gasoline varies but at the point of writing (2021-05-18) the cost was 15,79 SEK/l for gasoline E5 (Tanka, n.d.). This means it would cost around 13 000 SEK per year and thus driving an EV would save 9900 SEK per year. The economic achievements are to save:

- Bronze: 1000 SEK (takes around 1 month)
- Silver: 10 000 SEK (takes around 1 year)
- Gold: 100 000 SEK (takes around 10 years)

The sustainability achievements relate to reduced emissions compared to if the car would be powered by fossil fuel. The specific levels of the sustainability achievements were decided upon by calculating how much emission an EV saves on average compared to fossil fuel cars each year. Different EV's have different consumption. According to a study made by Recharge the most efficient electric cars used 16 kWh/100 km while the less efficient cars used around 24 kWh/100 km (Fröderberg, 2020). Based on this an average of 2 kWh/10 km was used and together with that an average private car drives 12 000 km per year it was calculated that an average EV consumes around 2400 kWh/year. The energy mix in Sweden emits around 46 g CO_2eq/kWh (ElectricityMap, 2021) meaning that an EV emits around 110 kg CO_2eq per year. For fossil fuel cars the average consumption is 0,68 l/10 km (Wedberg, 2015). Combined with the average distance of 12 000 km an average car uses 816 l/year. Gasoline emits around 3 kg CO_2eq/l (Miljöfordon, 2020) which means that the total emission is 2450 kg CO_2eq/year. This means that an EV saves around 2340 kg CO_2eq/year compared to a gasoline car. The sustainability achievements are to save:

- Bronze: 1000 kg CO_2eq (takes around half a years)
- Silver: 5000 kg CO_2eq (takes around 2 years)
- Gold: 10 000 kg CO_2eq (takes around 5 years)

11

DISCUSSION

In this chapter different aspects that might have affected the outcome of the project is discussed. This includes a discussion on whether the final result fulfills the aim, what could have affected the outcome of the tests and ethical and sustainable considerations related to the work with this thesis. Lastly, proposals for further development of the design solution are discussed.

11.1 Aim & final result

The aim of this thesis project was to investigate what factors affect people's electricity consuming behaviour, as well as how the flow of electricity throughout the household, including solar panels and electric vehicles, could be visualised for users to understand their environmental impact. The aim is believed to be fulfilled by the final solution and the research questions have thus been answered. The final solution fulfills the identified guidelines and thus meets the needs of users wishing to monitor their electricity consumption. In addition to the final design solution, insights have been identified and are an important part of the result. The insights provide an understanding of what to keep in mind when designing electricity monitoring devices.

There are some concerns regarding the final results that will need to be investigated further, to ensure the validity of the result. When investigating behaviour change it is a challenge to evaluate the effect long-term. It might be that the users use the solution frequently initially and actually do change their behaviour, but as the novelty has worn off they might retract to the previous behaviour. The actual consumption has not been investigated, but the study has relied on participants' self reporting. This might have altered the result, as there is a risk that the participants reported a more favourable result than what is true. There is also a risk that the participants did not remember the exact details of things they reported, as the studies were conducted detached from the behaviour itself. Also, as the solution has not been tested with users in their everyday life, the behaviour change can thus not be evaluated. What has been investigated however, is how the participants believe they will behave if they had access to an app like this. It is furthermore important to note that this study was conducted in early spring, which might have affected the monthly consumption reported by the participants.

Another crucial concern is whether the solution will be appealing for all users. There were some concerns during the evaluation if regular users without solar panels or EV's will find the app interesting, they are, after all, the largest user group. However, the information available to users without solar panels or an EV are similar or more extensive in comparison to the information available in other electricity monitoring apps. The version of the app presented in chapter *10 Final solution* is the one a user with both solar panels and an EV would use, this is because integration of the two are a crucial part of the aim of the thesis. For successful implementation of the solution it is important to remember that most users with solar panels or EV already use other applications to track electricity production and consumption. Therefore the application must be trustworthy and work as intended for those users to choose this app instead of their other ones. However, if the implementation of PV and EV is successful, those users will benefit from having access to all information in the same application, which is something many users desire.

Finally, it is important to note that the design proposal includes information on real time energy distribution throughout the home. Such extensive information might not be available to most users today, as smart appliances are required to track the data with that frequency. However, this thesis project has focused on an innovative solution that might be possible to implement within a timeframe of 5 years.

11.2 Test

A factor greatly affecting this thesis project has been the COVID-19 pandemic. Due to the circumstances, face-to-face interviews and testing have been difficult to perform. This affected the way the exploration phase was executed. Due to limited access to users caused by the pandemic, all interviews were held remotely. If it would have been possible to meet with users face-to-face it is likely that the exploration would have been executed differently. It would, for example, have been useful for the understanding if it would have been possible to visit users who have solar panels or an EV and observe how they interact with it in the context of their own home. As this was not possible, the understanding of their interaction has been forced to rely on their explanation of it. The circumstances caused by COVID-19 also affected the way the evaluation was executed, but the evaluation was also affected by lack of time. The concept was thereby evaluated with friends and family, and partly remote. Even though the participants were different types of users, their opinions might be affected and thereby decreasing the validity.

The assessment of the app can have been affected by not testing on a mobile screen. For example text appearing sufficiently large when shown on a computer screen might not actually be visually clear when read on a mobile screen. If it would have been able to meet with users to evaluate the app on a mobile screen, more thorough feedback might have been received and the result might have been different.

When reaching out to users to answer the questionnaire in the *Exploration* phase to receive a basis for statistics and socio-demographic factors, the people reached might not be representative for society as a whole. The questionnaire was partly shared in Facebook groups with people having and wanting to discuss solar panels, EV's and EHV's. Thereby the share of people having solar panels and (or) EV's in the statistics presented from the studies conducted in this thesis project is larger than for Sweden in total. Sharing the questionnaire in the Facebook groups mentioned and among peers at Chalmers University of Technology has furthermore probably resulted in mostly reaching users with higher education and higher income groups.

11.3 Ethical & sustainability considerations

Sustainable development has been an important aspect throughout the entire thesis project. This project can be considered to contribute to the UN Development Goal for sustainable energy for everyone. This thesis is believed to contribute to this goal by facilitating for users to use energy more efficiently and to be more aware of the environmental impact of their consumption. This will have positive effects in terms of environmental sustainability.

The design solution aims to decrease the electricity consumption, which affects both end users and electricity retailers. The goal of the project might thereby affect the electricity retailers negatively, which is important to mention as it is the electricity retailers that are Eliq's actual customers. However, electricity companies are looking for a way to create greater value for their customers, which the design solution is believed to contribute with.

This project has aimed to change the behaviours of the users of the solution, thus ethical aspects should be discussed. It can be discussed whether it is ethically correct to try to influence people's electricity consuming behaviour, and whether it is up to the designer to decide on behalf of the user what is the right and wrong behavior within the user's own home. However, the intended behaviour change is considered to contribute to a more sustainable use of electricity. Furthermore, the design solution does not force a behaviour change onto the users, but simply aims to motivate them to make the change for themselves.

When collecting data from users, both via questionnaires and interviews, GDPR has been followed. The participants have been informed of their anonymity, and their answers will not be used for further work besides this thesis project. In questions asking for personal or sensitive information (e.g. salary) in the questionnaires, the option of "I would not like to share" was provided.

11.4 Further work

There were some needs identified as to which solutions were outside the scope of this project. These were not focused on but guidelines were written down for future reference. One category of these were notifications, which are useful to create awareness of special or unusual circumstances. It was identified that users should be notified when consumption is unusually high and what the cause is, if charging of the EV has stopped unexpectedly and why, when new information is available in the app, when the energy mix deviates from normal and when demand for electricity is high. The details however still need work, for example the design of the notifications, the exact formulations and what the limits should be for unusually high consumption, deviation from normal and high demand.

In the future it would also be relevant to investigate whether it would be possible to integrate the app with smart homes and products. It is an emerging trend and it was found to be a desirable function. It might also make it easier to track the consumption of these products which would enable providing the user with information on consumption and cost of specific actions. Users believed this would be interesting to know and would motivate them to have more environmentally friendly behaviour.

Other areas which have been identified to be important but outside the scope of the thesis and thus needing more work are to provide individual advice on how to decrease consumption, provide correlation between consumption and external factors and to provide monthly and weekly consumption reports.

Further evaluation would also be needed. An evaluation with real users over a longer period of time would more accurately assess how the users actually interact with the app, what functions they use and their likes and dislikes. A longer test would also better evaluate the long-term effects of energy saving incentives and the long-term engagement of the app. Further evaluation should also include users who own solar panels or EV's since these groups were not able to be part of the concept evaluation conducted for this project. Even though useful feedback was received from people who did not own solar panels or EV's, real owners would know better what information they would be interested in. The evaluation should also include a higher number of people for higher statistical viability.

Finally, if the solutions developed in this thesis are to reach the real end users it would first need to be implemented in the app. The new functions would need to be integrated with the existing app and coexist in an harmonious way so that the holistic experience would be as pleasant as possible. Implementation would also require programming and new types of data from the end users, such as information from their solar panels. The design would also need to be adjusted to fit the design themes of Eliq's various customers.

CONCLUSION 12

In this chapter the conclusion of this thesis will be presented. The research questions which this thesis has investigated will here be answered.

How can the energy flow in a household be visualised?

The flow of energy has been visualised both with a 3D figure and with a more schematic figure. In the 3D figure the user can see energy rays between a representation of their house and the electric grid, and in the case the user owns solar panels or an EV the user can see how the energy flows between these units as well. In the schematic figure the user can see more clearly how the energy flows as well as how much energy.

How can electric vehicle charging be incorporated?

The EV has its own page and can be reached from the bottom menu. The electricity consumption used for charging the EV is separated from the rest of the household consumption in order to better explain sudden spikes in electricity usage. The EV also has its own colour, dark blue, which is used throughout the app for features related to the EV.

How can domestic solar power production be incorporated?

The domestic solar power production also has its own page and can be reached from the bottom menu. The colours yellow and orange are used to symbolise solar production. It is visualised together with consumption and the user can see both total production, total consumption and their net value over different time periods.

How can users be motivated to reduce their energy consumption?

The users can be motivated in several ways. The main functions meant to motivate users are the polar bear which ranges from happy to sad and gives a summary on the monthly consumption, general feedback from the consumption diagrams and the consumption goals. Users can set their own consumption goals, follow the progress and see previous completed goals.

What factors affect electricity consuming behaviour?

Electricity consuming behaviour can be affected by various sociodemographic factors. Low income households are generally more motivated to save electricity and value their economy higher than higher income households who generally value the environment higher. Families without children can more easily affect their consumption than those with children. Generally, households living in detached houses use more energy, are more aware of their consumption and can affect their consumption to a larger extent than those living in apartments. Furthermore, awareness, environmental attitudes and habits can also affect electricity consuming behaviour.

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Appendix A: Questionnaire survey 1

Hej, vad roligt att du klickade dig in på vår enkät! Vi heter Elin Lindström och Elin Wieslander och går sista året på Teknisk Design på Chalmers. Under våren håller vi på med vårt exjobb där vi undersöker hur energiflödet i hemmet kan visualiseras för att underlätta för användarna att förstå sin elkonsumtion, samt att motivera dem att minska den. Syftet med enkäten är att få en inblick i hur olika hushåll konsumerar el och hur de håller koll på sin konsumtion. Enkäten tar ca. 5-10 min.

Du kan när som helst välja att avbryta enkäten. Dina svar kommer endast användas under detta arbete och kommer sedan raderas. Om du väljer att inte fylla i din mailadress i slutet är du helt anonym och dina svar kommer inte kunna härledas tillbaka till dig.

Om dig och ditt hushåll

Hur bor du?

- Villa
- Radhus
- Bostadsrätt
- Hyresrätt
- Annat____

När byggdes din bostad?

- 2015 eller senare
- 2000 -2014
- 1980-1999
- 1960-1979
- 1940-1959
- Innan 1940
- Vet inte

Hur värms din bostad upp?

- Fjärrvärme
- Bergvärme
- Jordvärmepump
- Elvärme
- Ved-/Pelletspanna
- Oljepanna
- Luft-luftvärmepump
- Luft-vattenvärmepump

- Frånluftsvärmepump
- Annat_____
- Vet inte

Hur många är ni i varje ålderskategori i hushållet? (0-10, 11-17, 18-25, 26-65, 66<)

- 1
- 2
- 3
- Fler än 3

Har du eftergymnasial utbildning (inkl pågående)?

- Ja
- Nej

Om ja, berätta gärna inom vad!

Vad är hushållets totala nettoinkomst per månad?

- Mindre än 20 000
- 20 000 - 40 000
- 40 000 - 60 000
- 60 000 - 80 000
- 80 000 - 100 000
- Mer än 100 000
- Vet inte
- Vill inte ange

Under den senaste månaden, hur många dagar i snitt brukar det vara någon hemma varje vecka?

Har du/ni varit hemma mer under COvid-19? Om ja, har du märkt att det påverkat elräkningen?

Elkonsumtion

Känner du att du har koll på din/er energiförbrukning?

Inte alls 1 2 3 4 5 Jag har stenkoll!

Ungefär hur mycket el brukar ditt hushåll förbruka under en vanlig månad?

- Mindre än 100 kWh
- 100-300 kWh
- 300-500 kWh
- 500-1000 kWh

- 1000-1500 kWh
- 1500-2000 kWh
- 2000-3000 kWh
- Mer än 3000 kWh
- Vet inte
- Vill inte ange

Hur håller du koll på din elförbrukning? (T.ex. månadsfaktura, hemsida, app)

Vad tror du drar mest el i ditt hushåll?

Har du tagit några åtgärder för att försöka minska din elförbrukning? Vad i så fall?

Hur mycket upplever du att du kan påverka din elkonsumtion?

Kan inte påverka alls 1 2 3 4 5 Jag har full kontroll

Hur viktigt är det för dig att försöka minska din elförbrukning?

Inte alls 1 2 3 4 5 Superviktigt

Om det är viktigt för dig, vad motiverar dig mest? (T.ex. ekonomi, miljö, sociala faktorer…)

Solceller

Har du en egen solcellsanläggning på ditt hus?

- Ja
- Nej

Om JA:

Hur länge har du haft egna solceller?

Varför valde du/ni att installera solceller?

Hur håller du koll på produktionen?

Hur har installationen av solceller påverkat din elräkning?

Har installationen av solceller påverkat hur du använder el? (t.ex. på andra tider, mer/mindre…)

Vad händer med överskottselen som inte konsumeras? (t.ex. lagras på batteri, säljs etc.)

Elbil

Har du elbil?

- Ja
- Nej

Om JA:

Från vilken tillverkare kommer din elbil?

Har du tillgång till någon hemsida/app där du kan få överblick över laddningen? Om ja, vilken?

Varför valde du att köpa en elbil?

När på dygnet brukar du vanligtvis ladda den? Är det någon speciell anledning till att du laddar under den tiden?

Kan du fjärrstyra och/eller schemalägga laddningen?

Om JA på både solceller och elbil, även:

Påverkar produktionen från solcellerna hur/när du väljer att ladda din elbil? Hur?

Tack så mycket för att du ville svara på den här enkäten, det är till stor hjälp för oss! Vi kommer senare under arbetet genomföra fler användarstudier. Om du skulle vilja ställa upp så skriv gärna in din mail här nedan så kanske vi kontaktar dig längre fram i vår! Det skulle kunna handla om någon form av dagboksstudie eller en telefonintervju, eller något helt annat. Du får självklart tacka nej om du skulle ändra dig längre fram. Tack på förhand!

Appendix B: Affinity diagram result

Invoices/statistics

- Prosumers wishes to keep track of production, especially during sunny weather
- Some participants think the invoice is insufficient
- Some participants think the invoice is cluttered and incomprehensive
- Participants think diagrams are easier to comprehend than only numbers
- Participants would appreciate being able to correlate temperature and consumption in the same diagram
- Participants want to be able to compare different time periods

Guidelines:

- Enable prosumers to continuously follow production
- Provide correlation between consumption and external factors (e.g. temperature, daylight…)
- Enable comparisons between time periods

Distribution in household

- Participants want to know how the electricity is distributed in the home
- Participants want to know when their consumption is unusually high, and why.
- Participants want the EV to be a separate entity from the rest of the household

Guidelines

- Provide detailed and personalised visualisation of the distribution of electricity
- Separate EV consumption from the household consumption.
- Notify user when consumption is unusually high, and what the cause is

People are motivated and get more knowledge about their consumption if it is categorised

Wish to see

- Participants want to be able to interlink electricity information with other smart solutions
- Participants believed that a nice-looking app would be used more frequently
- Prosumers want to know total production, sold electricity and bought electricity
- Participants would find it interesting to know the cost of specific actions
- People driving an EV want to:
    - Remotely turn on the heat
    - See current charge
    - Schedule charging to when electricity is cheap
    - Set a limit to maximum charge
    - Get a notification if and why charging has stopped unexpectedly

Guidelines:

- Provide quick overview of total production from solar panels, consumption and sold and bought electricity
- Provide information of consumption of specific actions
- Provide information of cost of specific actions
- Provide information on current charge
- Enable scheduling of charge to times when electricity is cheap or low demand
- Enable remote adjustments of heat
- Enable adjustments of maximum charge
- Notify user if charging has stopped unexpectedly and why

Visually appealing app is important for high use frequency

See in hindsight

- Participants want to be able to adjust their consumption according to price of kWh
- Participants want to view consumption in real time
- Participants want to see total consumption and price thus far each month
- Participants want to see consumption distributed over hours of the day

Guidelines:

- Provide information of how price of electricity varies over time
- Provide real time consumption data
- Provide total consumption of the month thus far
- Provide total cost of the month thus far
- Visualise how consumption is distributed throughout the day

Compare

- Participants find it interesting to compare energy consumption between months
- Participants are motivated by challenging themselves
- Participants did not find it relevant to compare with similar homes
- Participants stated that it's important to remember everyone has different circumstances and possibilities

Guidelines:

- Enable comparisons between months
- Enable individual goal-setting
- Clear visualisation of improvements/worsenings

Feedback as motivation

- Participants want to be able to view the effect of their energy saving measures
- Participants believed that rewards are more effective than punishments
- Feedback motivates and triggers reflection

Guidelines:

- Provide positive encouragement when user has made improvements

Feedback motivates and triggers reflection

"Unable" to decrease/don't care

- According to the participants, factors inhibiting a decrease in consumption can be:
    - Children or other family situations
    - Wanting the home to give a cozy impression
    - Unavoidable basic activities (e.g. cooking, laundry…)
    - Amount of daylight
    - Temperature
- Participants feel unmotivated to decrease consumption or to change electricity provider due to the small economic gain
- Participants believe it's difficult to further decrease consumption as measures have already been taken
- Participants are unwilling to make changes that would affect quality of life

Guidelines:

- Visualise gain in different units
- Provide individual advice of how to decrease consumption

Participants are unwilling to make changes that would affect quality of life

Environment

- According to participants, environmental motivators can be:
    - Future generation
    - Strong sense of responsibility
    - Wanting to help where possible
    - Avoid unnecessary waste of resources
    - Simple measures to make a difference
    - Fear of consequences of climate change
- Some participants believe altruistic benefits are superior to financial gains

Lack of power/capacity

- Participants request information on variations of strain on the grid and price.
- Participants want knowledge of peak demand.
- Participants would benefit from seeing a connection between peak demand and "dirty" energy.
- Some participants highlighted the importance of steering consumption to low-demand times.

- Some participants are limited in when they use electricity to the few hours they spend at home in the evening.

Guidelines:

- Provide information on variations in strain on the grid.
- Provide notification when demand for electricity is high.
- Provide information when "dirty" energy is being used.

It's important to acknowledge that many consumers feel constrained in when to use electricity, as they only spend a few waking hours at home during the week.

Ignorance

- Participants are unaware of what consumes energy and how much.
- Participants don't know what they can do to save electricity.

Guidelines:

- Visualise how the electricity consumption is distributed in the home.
- Provide personalised advice on how to decrease consumption.

Motivations from the environment

- Participants mention these as the environmental consequences they care most about:
    - The damage of the oceans
    - Dying coral reefs
    - Plastic islands in the oceans
    - Polar bears starving
    - Exploitation of natural resources
    - Global warming
    - Deforestation of rainforests
    - Animals suffering due to littering
    - Destruction of natural environments with landfills and garbage
    - Health consequences of people breathing in pollutions

Don't like a website

- Many participants were unsure whether they have access to an app, or had recently discovered it
- Participants feel that logging in to a website requires too much effort.
- Some participants don't see the point in using a website.
- Participants expressed a preference for a mobile application solution.

Making the log-in process simple is crucial for high engagement

Reasons for getting solar panels or EV

- Participants mentioned the following motivators to install solar panels:
    - Interested in the technology
    - Environmental reasons
    - Economical reasons
    - Investment for future
    - Social status
    - Participate in the environmental debate
    - No reasons not to
    - Practise as you preach
- Participants mentioned increased knowledge and motivation from discussions with others.
- Some participants stated that buying an EV enables utilising a larger share of their own solar power.

Production and selling

- Participants stated that the demand for energy does not correspond to time of production.
- Participants mentioned that the level of interest in monitoring the production was higher when newly installed.

Struggle with most sun during hours of low demand/not being home.

Struggle with maintaining interest in the monitoring when nyhetens behag har lagt sig.

Reasons to decrease

- Participants mentioned the following motivators to decrease energy consumption (besides environment & economy):
    - It's fun
    - Dislike of inefficient appliances
    - Health factors to decrease sedentary lifestyle
    - Electricity self-sufficiency
- Participants mentioned that other motives for decreasing consumption are also important as they still contribute to using less energy.

People are motivated by a lot of different things.

Want to purchase green electricity

- Participants prioritise availability of renewable energy when choosing an electricity provider.

Guidelines:

- Highlight what source(s) the electricity is derived from.

Appendix C: Guidelines Evaluation

Total consumption

Guideline	Prio	Yes/no
Provide total consumption of the month thus far	1	**Y**
Provide total cost of the month thus far	1	**Y**
Visualise how consumption is distributed throughout the day	1	**Y**
Provide detailed and personalised visualisation of the distribution of electricity	2	**Y**
Separate EV consumption from the household consumption	2	**Y**
Enable consumption comparisons between time periods (hours, days, weeks, months, years)	1	**Y**
Provide correlation between consumption and external factors (e.g. temperature, daylight…)	3	**N**
Provide monthly and weekly consumption reports	3	**N**
Provide history of charging of the EV	2	**Y**
Provide monthly cost of EV charging	2	**Y**

Real time data

Guideline	Prio	Yes/no
Provide real time consumption data	1	Y
Provide information on current charge [EV]	1	Y
Provide real time production data	1	Y

Awareness

Guideline	Prio	Yes/no
Provide information of consumption of specific actions	3	N
Provide information of cost of specific actions	3	N
Visualise *gain* in different units (e.g. SEK, kWh, CO_2eq)	1	Y
Clear visualisation of improvements/worsenings	1	Y
Provide forecast on consumption based on earlier behaviour	2	Y
Provide positive encouragement when user has made improvements	2	Y
Provide trivia on how one can decrease consumption	3	Y
Provide individual advice on how to decrease consumption	3	N

Provide information on repayment of solar power	**2**	**Y**

Grid information

Guideline	**Prio**	**Yes/no**
Provide information on effect tariffs	**1**	**Y**
Highlight what source(s) the electricity is derived from	**2**	**Y**
Show CO_2eq/kWh for the electricity mix of the household	**2**	**Y**
Provide information of how price of electricity varies over time	**1**	**N**
Provide positive encouragement when peak demand is avoided	**3**	**N**

Control

Guideline	**Prio**	**Yes/no**
Enable remote adjustments of heat [EV]	**3**	**S**
Enable adjustments of maximum charge [EV]	**1**	**Y**
Enable scheduling of charge to times when electricity is cheap or low demand [EV]	**1**	**Y**
Enable individual goal-setting	**2**	**Y**
Provide updates on the set goal.	**2**	**Y**

Solar power production

Guideline	Prio	Yes/no
Enable prosumers to continuously follow production	1	Y
Enable production comparisons between time periods (hours, days, weeks, months, years)	1	Y
Provide quick overview of total production from solar panels, consumption and sold and bought electricity	1	Y
Visualise production from individual solar panels	2	Y

Visualisation

For guidelines regarding Visualisation and Usability, *Somewhat* has been added as an evaluation criteria. This is because it might be that the guideline has been fulfilled in some places in the solution, but in others it is lacking or has partially been fulfilled.

Guideline	Prio	Yes/no/ somewhat
When different measurements are visualised in the same diagram, use different types of charts to increase clarity	2	S

When different measurements are visualised in the same diagram, charts should not severely cover each other	1	**Y**
Use a neutral colour for charts which cannot be influenced by the user	1	**Y**
When visualising production from individual solar panels, darker colours shall symbolise higher solar irradiation	2	**Y**
Malfunctioning solar panels shall be visualised in a deviating way	1	**Y**
Use yellow-orange for attributes regarding solar power	2	**Y**
Use dark blue for attributes regarding EV	2	**Y**
Use grey for neutral and/or non-active attributes	2	**Y**
Use turquoise for clickable and/or activated options	2	**S**
Use light blue to symbolize electricity consumption	2	**Y**

Usability

Guideline	**P r i o**	**Yes/no/ somewhat**
Be consistent with choice of colour for attributes	1	**Y**
Use recognisable symbols	2	**Y**
Symbols shall all have a similar design language	2	**Y**
Avoid displaying several attributes at the same time, in consideration of user resources	2	**Y**

Make the most important information the most noticeable	1	**Y**
Make it obvious what attributes are clickable	1	**S**
Make it obvious what option is chosen	1	**Y**
A novice user shall be able to easily navigate the app	2	**Y**
Texts smaller than 17 pt shall have a minimum colour contrast ratio of 4,5:1	1	**Y**
Bold texts or texts larger than 17 pt shall have a minimum contrast ratio of 3:1	1	**Y**