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Improving the user experience for battery owners providing ancillary services

A human centered design process of an interface for residential battery owners connected to a virtual power plant making a sustainable choice more attractive

Master's thesis in Industrial Design and Engineering

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Department of Industrial and Materials Science
CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

To achieve a more sustainable society, the energy grid will have to transition from non-renewable energy sources to renewable ones. This transition includes several challenges. Renewable energy sources (RES) such as wind and solar power are to a large extent affected by weather. This causes intermittence in energy production. With this intermittence the challenge of keeping the power grid stable, resilient and of high quality becomes even more challenging.

One solution to the challenge is controlling energy sources jointly through a Virtual Power Plant (VPP). The energy sources can act as one single power plant even if they are geographically separated. These VPPs can help to stabilize the power grid to allow for a larger share of RES than today.

There is possibility for home owners to contribute to a more sustainable power grid by enrolling their residential batteries in a VPP to perform ancillary services, while also gaining revenue. The demand for ancillary services are steadily increasing and the Swedish Transmission Systems Operator (TSO), Svenska Kraftnät, is increasing their budget for buying ancillary services each year.

This thesis develops an interface for users enrolled in a VPP. The interface is intended for a mobile phone and complements the current web based interface. The aim is that the customer experience of being enrolled in a VPP will become more attractive with the new interface. The interface monitors the battery as part of a VPP as well as solar electricity production, energy usage and the economy of the system.

By making the experience of being a member of a VPP more attractive, this thesis indirectly contributes to a more sustainable society.

Keywords: Virtual power plants, aggregator, ancillary services, residential batteries, user interface, project, thesis.

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Gustav Brogren & Jacob Victorin, Gothenburg, 2023-06-20

List of Acronyms and Glossary

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

AC	Alternating current
BESS	Battery Energy Storage System
BRP	Balance Responsible Party
DER	Distributed Energy Resource
DSO	Distribution System Operator
EA	Energy Arbitrage
ESS	Energy Storage System
EIB	EnergyInBalance
FCR	Frequency Containment Reserve
FCR-D	Frequency Containment Reserve - Disruption
FCR-N	Frequency Containment Reserve - Normal
FFR	Fast Frequency Reserve
HCI	Human Computer Interaction
Hi-Fi	High Fidelity
kWh	Kilowatt hour
kWp	Kilowatt peak
Lo-Fi	Low Fidelity
Mid-Fi	Medium Fidelity
Power	A measure of work (e.g. kW) at a given moment.
PS	Peak Shaving
PV	Photovoltaic
RES	Renewable-based Energy Sources
RiSE	Research institute of Sweden
RtD	Research through Design
SoC	State of Charge
SvK	Svenska Kraftnät
TSO	Transmission System Operator
UI	User Interface
UX	User Experience
VPP	Virtual Power Plant

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1

Introduction

This chapter begins by presenting the layout of the thesis and then provides a background of the project as well as its aim and goal.

1.1 Layout of the Thesis

The layout of this thesis is as follows:

- **Introduction:**
  Thesis background, aim & goal.
- **The Nordic Power Grid:**
  Description of the Nordic power grid, section 2.1 in order to get enough knowledge to understand the thesis.
- **Design Methods & Theories:**
  Chapter 3 presents used methods and theories.
- **Design Process:**
  Implementation and execution of used theories and methods, chapter 4.
- **"Results:":**
  The chapters labeled with "Results:" present the results from each phase in the process.
- **Final Design:**
  Chapter 8 shows the final version of the prototype and its features.
- **Future Design Work:**
  Chapter 9 highlights several future ideas for expanding the design.
- **Discussion & Conclusion:**
  The discussion chapter 10 and conclusion chapter 11 is presented.

Reading in short form
This thesis is possible to read in short form by reading the background (section 1.2) aim and goal (section 1.3) and the Final Design (chapter 8). This reading provides some background on the thesis and the outcome of the design work performed.

1.2 Background

The energy grid is transitioning towards less reliance on fossil energy and more reliance on renewables (wind, water, solar). Renewable energy sources (RES) are dependent on winds blowing, sun shining or rain falling, thus are not plannable in the same way as non renewable energy sources. In order to keep the frequency of the grid stable, the amount of produced electricity needs to match the demand at any given moment (Svenska Kraftnät, 2021a). To achieve this the transmission system operator (TSO) utilizes various measures and in Sweden a market for ancillary services has been created. Ancillary services are supports functions in the electricity grid to ensure stable and reliable operation. This makes sure the supply of electricity matches the demand in real-time, by continuously balancing the generation and consumption of power. They are quick and reactive. This helps prevent deviations in grid frequency, which can lead to disruptions or even blackouts

A key difference between RES and non-RES is that the latter has larger generators which work synchronously to match the frequency of the grid. In the event of a disruption to the grid such as a power plant failure, the inherent inertia of the generators give the system time to respond (Denholm et al., 2020). RES has comparatively less inertia and in order to keep the grid frequency stable, new solutions are evolving. One such solution is to use batteries to support the grid. As battery energy storage systems (BESS) have a fast response, a wide range of applications that increase system stability are possible. Examples of applications are load leveling (storage of power for periods of higher demand), peak shaving (manage overall electricity demand to decrease short-term spikes), black-start capability as well as a synthetic spinning reserve used to stabilize the frequency (Mercier et al., 2009).

The aggregation of multiple energy resources enables smaller energy resources to be part of bidding on the ancillary services market of FCR (Frequency containment reserve) and FFR (Fast Frequency reserve), as a combined power of more than 0,1 MW is needed to place bids. To enable this, services are emerging where companies enroll companies and home owners batteries and act as aggregators in what can be called a Virtual Power Plant (VPP). A VPP is a system that consists of various energy sources which together can provide energy and ancillary services. These resources are centrally managed by an Energy Management System (EMS), enabling them to function as a single power plant (Roozbehani et al., 2022). CheckWatt is a company that provides this service which allows residential and commercial actors to help stabilize the frequency of the grid and earn revenue from their energy resource (CheckWatt, n.d.). Their virtual power plant is called Currently and for the customers connected, their system status is visualized in EnergyInBalance (EIB), a desktop portal that collects data regarding electricity use, production, solar, batteries, grid connection and more (CheckWatt, n.d.).

1.3 Aim and Goal

The aim of this thesis is to identify the user goals and needs of homeowners enrolled in services delivering smart control of residential BESS and monitoring of residential power production and usage. This will lay the foundation for the creation of a solution that satisfies the found goals and needs in order to improve the user experience. The thesis is done at CheckWatt AB, which has such users enrolled in above mentioned services since December 2022. CheckWatt works with a range of customers varying from larger industries to smaller residential systems. This project aims to focus on the residential segment as this is an area that requires catering to more needs than the industry sector, as the customer group has a much larger variation of expertise and background.

The goal is fulfilled by delivering a requirement specification of user goals and needs with a human centered design process, as well as a high-fidelity interactive prototype. To verify fulfillment of user goals, the prototype is tested and assessed through various user tests. The final design will work as a basis for further development.

2

Description of the power grid

This chapter provides theory about renewable energy sources (RES) and the Nordic power grid. It also provides theory about the trading of ancillary services and why they are needed in a grid with increasing intermittent power production.

2.1 The Nordic Power Grid

The Nordic power grid is an interconnected electricity network that spans across Denmark, Norway, Sweden, and Finland (Svenska Kraftnät, 2022b). The system enables efficient exchange of electricity as well as balancing of supply and demand across these countries. This interconnected grid plays a role in the region's electricity market and contributes to a stable, sustainable, and flexible energy supply. The countries share a synchronous area and acts as one single power grid (Svenska Kraftnät, 2022b).

Energy mix

The Nordic countries have a diverse energy mix. It has a significant share of renewable sources such as hydropower, wind power, solar power. In 2021, the energy distribution in Sweden consisted of 43% hydropower, 31% nuclear power, 16% wind power, 9% thermal power, and 1% solar power (Langlet, Charlotte & Arvidsson, Mattias, 2022). Each country has its unique resources and capacities, allowing them to complement each other and maintain a stable and reliable power supply.

Transmission

The high-voltage transmission lines connect power generation facilities to the grid, allowing for the long-distance transportation of electricity. TSOs in each country are responsible for managing the national grids and maintaining their stability. The TSOs in the Nordic region includes Svenska Kraftnät (Sweden), Energinet (Denmark), Statnett (Norway), and Fingrid (Finland). On a local level distribution system operators (DSOs) are responsible for the power grid.

Interconnections between countries

The Nordic power grid is interconnected through a series of high-voltage transmission lines and undersea cables that link the countries, enabling electricity to flow across national borders. These interconnections facilitate power trading and help balance supply and demand across the region. They also allow for the integration of intermittent renewable sources, such as wind and solar, by transferring excess power from areas of high production to areas with higher demand. Sweden is AC (alternating current) connected with Finland, Norway and Denmark. As these countries share a synchronous area (synchronized frequency of 50 Hz) (Svenska Kraftnät, 2022b) a disturbance in Finland will affect the power grid in Sweden, for instance. The outside of the Nordic Power grid is connected through DC (direct current) with other synchronous areas. These do not share frequency synchronization.

Trading

Electricity within the Nordic power grid is traded on Nord Pool, a power exchange platform that facilitates transparent, competitive, electricity trading between power producers and consumers. The market comprises day-ahead and intra-day segments, enabling short-term and real-time power trading. Ancillary services, such as frequency containment reserve (FCR) and automatic frequency restoration reserve (aFRR), are also traded on a marketplace, similar to energy trading. The provider of an ancillary service gets paid per kW kept available as a reserve.

The demand for being able to use resources flexibly (eg. reduce consumption when needed) is increasing to cope with congestion in local grids. Flexibility trading markets are being tested in various projects. Sthlmflex, an ongoing pilot project, offers a flexibility market in the Stockholm area. The market operates on the NODES platform, with trading conducted in a manner akin to energy trading on Nord Pool (Svenska Kraftnät, 2022a).

The final price of energy for the end customer consists of spot price (price is set by the hour) traded on Nord Pool as well as costs for transmission, taxes, subscription fees and in some cases power tariffs.

Today, the subscriptions fees from the DSOs are designed for the market and prerequisites of 10-20 years ago. The subscription fee is generally decided based on the size of the main fuse and is static. All electricity network companies must introduce a power tariff at latest on the 1:st of January 2027 (Energimarknadsinspektionen, 2022). A power tariff introduces a dynamic cost for the customer based on actual peak power usage, rather than the size of the main fuse. The dynamic pricing is meant to better reflect the actual costs for running the grid as well as cover investments to the grid and should give incentives to users to use the grid more efficiently (Energimarknadsinspektionen, 2022).

2.2 RES in the Nordic power Grid

Renewable energy sources (RES) are types of energy that are replenished naturally and continuously in the environment. They offer a sustainable alternative to traditional fossil fuels, which are finite and have a significant impact on climate change due to their greenhouse gas emissions. The Nordic power grid has a relatively large quantity of RES. This does however pose some challenges in managing the grid. The following RES play a role in the Nordic grid.

Solar Power

Although solar energy has a relatively small share in the Nordic power grid, there is growing interest in its potential. The long daylight hours in the summer months offer opportunities for solar power generation. Sweden and Denmark, in particular, have seen a steady increase in solar capacity, mainly through small-scale installations in the residential area. In 2022 Sweden saw an increase of grid connected photovoltaic (solar panels, PV) with close to 50% compared to the previous year (Energimyndigheten, 2023).

Wind Power

The Nordic countries have invested significantly in wind energy, with Denmark being a global leader in this sector. Favorable wind conditions and ambitious governmental targets have led to rapid expansion. Both onshore and offshore wind farms have been developed across the region. As a result, wind power has become a major contributor to the grid, particularly in Denmark, which generated 47% of its electricity from wind in 2020 (Wind Denmark, 2023).

Hydropower

Harnessing the positional energy of water to generate electricity. The backbone of the Nordic renewable energy mix, hydropower is the most significant source of electricity in the region, particularly in Norway and Sweden. The abundance of rivers and lakes, combined with a suitable topography, allows for the generation of large scale hydroelectric power. Norway, in particular, relies on hydropower for about 95% of its electricity production (Statistisk sentralbyrå, n.d.). In Sweden, this share is 35-45% (Energiföretagen, 2023). Hydropower provides a reliable, flexible, and quick response to fluctuating demand, enabling it to balance and support intermittent renewables like wind and solar power.

Biomass and Bioenergy

Biomass and bioenergy play a large role in the Nordic energy mix, particularly in Sweden and Finland. Forest residues, wood pellets, and biogas from agricultural waste and wastewater treatment plants are common sources of bioenergy. Biomass and bioenergy provide a stable and flexible energy source that complements intermittent renewables like wind and solar. The sustainability of biomass energy is however debated due to their high relative aggregate footprint (Hadian & Madani, 2015).

Summary

The Nordic power grid's reliance on renewable energy sources has facilitated the development of advanced energy markets, cross-border interconnections, and demand side management techniques. Some of the renewable energy sources (RES) are intermittent in their nature. Hydropower and biomass power can be regulated on demand to some extent, the regulating power is not unlimited. The intermittence of weather dependent RES such as solar and wind power poses new challenges in the energy grid as the consumption does not always match the weather. As RES increases new ways of handling these imbalances are needed in order to keep the power grid stable.

2.3 Svenska Kraftnät (TSO)

A transmission system operator (TSO) is responsible, on a national level, for transporting energy in the form of natural gas and electric power. The TSO is also responsible for keeping the quality and security of the electricity system intact (Biancardi et al., 2021). Svenska Kraftnät (SvK) is the Swedish TSO. One of the most important tasks of SvK is to keep the production and consumption of electricity in balance. The frequency of the grid is a clear indicator of whether balancing is achieved. When the frequency deviates too much from 50 Hz, the risk of service disruptions and blackouts increases. If the frequency drops, the production is too low/consumption too high. If the frequency increases the production is too high/consumption too low. The balance is illustrated in Figure 2.1. The Nordic synchronous area is kept at 50 Hz ± 0,1 Hz (Svenska Kraftnät, 2023a).

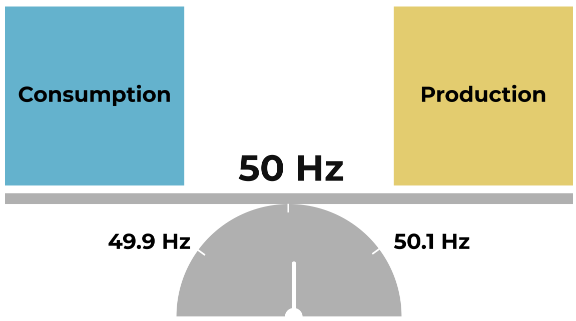

Figure 2.1: Energy balance between production and consumption

2.4 Balance Responsible Parties

The execution of the balance between production and consumption is done by a balance responsible party (BRP) (Svenska Kraftnät, 2023b). They are responsible for ensuring that the electricity consumption and production within their portfolio is balanced in real-time. The BRP aggregates the electricity generated by various producers and the demand from consumers, creating a balanced schedule to match the expected generation with the expected consumption. BRPs are financially responsible for the deviation, as they need to compensate for the discrepancy in the balancing market. A BRP is also the entity trading on the ancillary service market.

2.5 Flexibility in the Grid

Flexibility is a key aspect of the future power system. In the national electrification strategy presented by the Swedish government in early 2022 (Power Circle, 2022), it is highlighted that the ability to be flexible should be built into the power system and that opportunities for flexibility should be promoted when electricity-intensive activities, such as new industries, connect to the grid.

From a power system perspective, flexibility refers to the ability of the power grid to manage variability and uncertainty when it comes to the supply and demand of electricity, across all relevant timescales - from ensuring immediate stability in the system to ensuring long-term supply security. Flexibility can be generated from several different resources in the system: from production units such as wind, solar, and hydropower, to various types of energy storage, and components that can change their power consumption based on demand. When flexible resources are activated, flexibility can be made available in a cost- and resource-efficient manner. By offering activation of these resources, the grid customers who provide them can also become an asset rather than a burden on the system (Power Circle, 2022).

The following are aspects of flexibility and balancing services in the Nordic power grid.

Frequency Control

To maintain the stability of the grid, it's essential to keep the frequency close to the nominal value of 50 Hz. Frequency control involves managing the balance between electricity generation and consumption in real-time.

Voltage Control

TSOs and DSOs employ various techniques to regulate voltage levels, such as transformer tap adjustments, reactive power compensation through capacitor banks, and using generators capable of providing reactive power support.

Reserve Capacity

To handle unexpected changes in power supply or demand, the TSOs buy reserve capacity in the form of different services, for example ancillary services. They are activated in a specific sequence, depending on the severity and duration of the imbalance. Reserve capacity can be provided by various sources, including conventional power plants, hydroelectric facilities, energy storage systems, and demand response programs.

Demand Response

This approach involves adjusting electricity consumption patterns in response to price signals or grid conditions. By incentivizing consumers to shift their electricity use to periods of low demand or high renewable generation, demand response helps balance the grid, improves system efficiency, and reduces the need for additional peak generation capacity.

Energy Storage

Energy storage systems, such as batteries, pumped hydro storage, and thermal storage, can enhance grid flexibility by storing excess energy during periods of high generation and releasing it when needed. These systems help smooth out fluctuations from intermittent renewable sources as well as peak consumption periods.

Summary

In summary, flexibility and balancing services are important components of the Nordic power grid, ensuring its stability and reliability in the face of increasing renewable energy integration. By combining various technical and market-based solutions, the Nordic countries can manage the challenges of intermittent renewables and maintain a secure, sustainable, and efficient energy system. (Power Circle, 2022)

2.6 Ancillary Services

SvK has a range of tools and measures in order to balance the grid and to deal with disturbances, mainly reserve capacity. These services provide support for the energy grid. The three listed below (FCR-N up/down, FCR-N up/down and FFR up) are not the only services used, but relevant for this thesis. These three are reserves of active power that are automatically managed according to frequency deviations. The aim is to maintain the frequency within acceptable ranges during both normal operation and disturbances. These services are relatively new, FCR-D down was introduced on the ancillary services market the 1:st of January 2022.

FCR-N Up/Down

Frequency containment reserve - normal is the reserve for normal operation of the grid. The FCR-N operates between 49,90 Hz and 50,10 Hz. It needs to last for one hour and can regulate power both up and down. The service is traded daily on the marketplace. Providers are compensated on an hourly basis for keeping the energy sources **ready to take action** and **energy used.** Available **power** is what decides the compensation.

FCR-D Up/Down

Frequency containment reserve - disturbance is used when there are disturbances in the grid. FCR-D activates below 49,90 Hz or above 50,10 Hz. It needs to last for 20 minutes and can regulate power both up and down. The service is traded daily on the marketplace. Providers are compensated on an hourly basis for keeping the energy sources **ready to take action.** Available **power** is what decides the compensation.

FFR Up

The purpose of the fast frequency reserve (FFR) is to handle the initially fast and deep changes in frequency that can occur when disturbances happen and the inertia in the grid is low. FFR only regulates upward and activation within 1,3 seconds at a frequency of 49,7 Hz is needed. FFR is traded one year in advance.

2.7 Aggregators and Virtual Power Plant

In order to compete on the ancillary services market, a provider has to fulfill the minimum bid size. All of the above mentioned services have a minimum bid size of 0,1 MW. Energy resources whose power is smaller than 0,1 MW can be gathered and sold as a package. An aggregator collects several of these smaller resources and provides them as a package deal, through a BRP, on the market to gain revenue.

The collection of resources, for example battery energy storage systems (BESS) is known as a Virtual power plant (VPP). The resources share control and act as one entity even if they are geographically separated. It can consist of various energy resources which together can provide energy and ancillary services. These resources are centrally managed by an Energy Management System (EMS), enabling them to function as a single power plant (Roozbehani et al., 2022). The VPP can provide balancing of energy in the power grid. When consumption is larger than the production the VPP can pump energy into the grid. When production is high and consumption low, the VPP can draw energy from the grid. The power grid system always has to stay in balance, since electricity needs to be used at the same moment it is produced.

2.8 CheckWatt

CheckWatt is an aggregator who has put a VPP (named Currently) on the market. For a residential customer to join the VPP, they install a small computer that takes control of their BESS. When a battery is connected to Currently, the user can no longer control their battery themselves. The goal of the company is to create maximum economic profit for the BESS owner. In the past two years, the ancillary service of FCR-D has been most profitable 95% of the time (CheckWatt, n.d.). Apart from FCR-D, the battery can perform other services such as energy arbitrage (EA, charge when the electricity price is low) or peak shaving (PS, cutting power peaks). The connection of residential batteries to the VPP was introduced in December 2022.

CheckWatt works together with several BRPs in the ancillary market to offer services. Together, they place bids on the marketplace and if the bid is successful they collect revenue from SvK. The BRP shares a portion of this revenue with CheckWatt, who in turn allocates a part of it to the battery owner. An illustration of this can be found in Figure 2.2

At the time of writing, the FCR-D market is quite profitable. A residential battery owner with a 10 kW system can expect to earn an estimated 30,000 SEK annually. The bids can be found on SvK's portal Mimer. The market is predicted to drop somewhat as more actors enter. Meanwhile, SvK is allocating more resources to buy ancillary services.

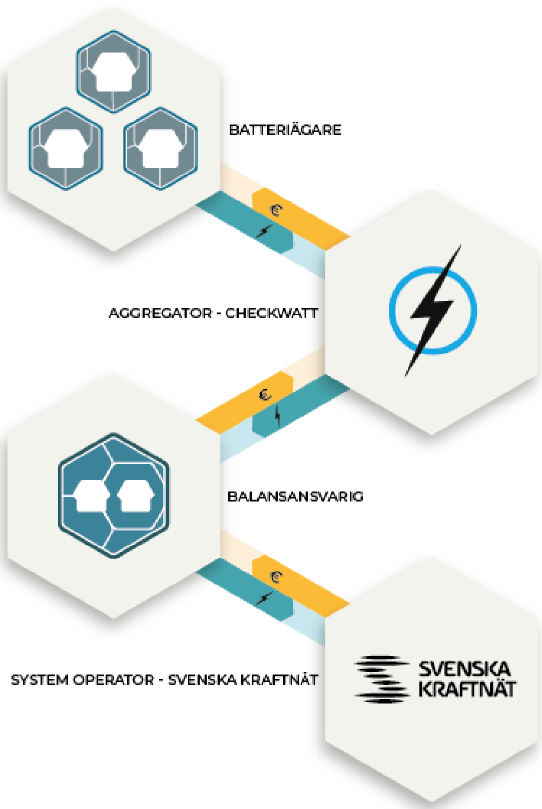

Figure 2.2: Diagram illustrating the actors in the VPP Currently and how they interact (CheckWatt, n.d.). Reproduced with permission

2.9 VPPs in a Sustainability Perspective

There is little doubt that an increasing amount of VPPs will have a positive impact from a sustainability perspective. VPPs promote the integration of renewable energy sources into the power grid. By efficiently coordinating diverse energy sources, they help overcome some of the challenges associated with renewable power, such as variability and intermittency. Both energy production from RES and load demand from consumers are forecast day ahead. The production forecast is, even if state-of-the-art models are used, typically 10% off in their calculations (Kong et al., 2022). Meanwhile, consumption forecasts can also be wrong (Zamani et al., 2016). This imbalance has to be solved for the grid to function correctly and non-intermittent energy sources such as hydro or non-RES production is currently being used. When the share of RES increase in the grid, there is a risk of this imbalance increasing. A VPP can help to bridge the imbalance, creating a more resilient power grid with the prerequisites needed for increasing the share of RES, transitioning from non sustainable energy sources (J. Liu et al., 2023; Power Circle, 2019; Svenska Kraftnät, 2021b).

Further, VPPs are often decentralized and distributed geographically. This reduces the impact of potential disruptions, such as natural disasters or equipment failure, on the overall power supply. Another effect of the geographical distribution is that it can reduce the need to build electricity transmission for peak usage. In a distributed energy source grid, the need for complicated transmission and distribution infrastructure can be reduced (J. Liu et al., 2023). Potentially, a VPP can replace the need for building new power lines when a geographic area increases its demand for peak power.

A VPP is an innovative solution to many of the challenges associated with transitioning to a more sustainable and resilient energy system. By facilitating the integration and efficient management of diverse energy resources, VPPs can help us reduce our carbon footprint, improve energy security, and create a more sustainable future (C. Liu et al., 2021).

2.10 Conclusion

This chapter has outlined how the Nordic power grid operates and the income models associated with ancillary services performed by VPPs with BESS. Further, it has argued that the services performed by VPPs contribute to a more sustainable society by making a larger share of RES possible in the grid, while maintaining reliable operation.

There is a possibility for home owners to contribute to a more sustainable power grid by enrolling their residential BESS in a VPP to perform ancillary services, while also gaining revenue.

3

Design Methods and Theories

This chapter contains a general description of the design methods used for this thesis. Overarching methods as well as methods linked to a specific phase or phases (see chapter 4) are described.

3.1 Overarching Methods

The following section presents the overarching methods used through the design process.

3.1.1 Human Centered Design

Human-centered design (HCD) is an approach to problem-solving and product development that focuses on understanding and addressing the needs, desires, and experiences of the end-users. It emphasizes empathy, user research, and iterative design to create solutions that are effective, usable, and enjoyable for the people who will use them. The goal is to solve the right problem in the right way that meets human needs and capabilities (Norman, 2013).

An HCD approach involves four activities that are iterated during the development.

- Observation
- Idea generation
- Prototyping
- Testing

The observation activity develops a deep understanding of the target users by conducting research, such as interviews, observations, and surveys, to gain insights into their needs, preferences, and pain points. Ideation aims to generate a range of possible solutions to address the identified user needs and problems. This step encourages creative thinking and collaboration between designers. Prototyping can be done with several different types of artifacts. Low-fidelity (Lo-Fi) or high-fidelity (Hi-Fi) prototypes help to visualize and test the proposed solutions. Prototyping allows designers to iterate quickly, identify issues, and refine their ideas based on user feedback. Testing ensures that design is successful. Conducting testing with the target users to evaluate the prototypes and gather feedback on their effectiveness, usability, and overall user experience. This step helps identify areas for improvement and creates tasks for further iterations (Norman, 2013).

3.1.2 Research Through Design

This project has used a research through design (RtD) process, in the focus of user experience (UX) design. In RtD, the aim is to generate new knowledge by understanding the current state and with the help of a design artifact, suggest a future improved state (Zimmerman & Forlizzi, 2014).

Zimmerman et al. (2007) highlights the interdisciplinary nature of HCI (human computer interfaces) and the need for diverse research approaches to address the complex and evolving challenges of interaction design. RtD is presented as a method that complements existing HCI research methods, such as ethnography, experimental studies, and theory building, by focusing on the generation of new knowledge through the process of designing.

RtD involves an iterative process that typically comprises three main phases: exploration, creation, and reflection. In the exploration phase, researchers engage in understanding the problem space, user needs, and contexts. The creation phase involves ideation, prototyping, and iteration of design solutions, with the designer actively engaged in shaping the material and digital artifacts. The reflection phase focuses on evaluating and documenting the design outcomes, analyzing the generated knowledge, and drawing insights from the process.

Gaver (2012) argues that expectations on creating extensible and verifiable theory from RtD should be moderated. However, verifying results from RtD should be possible.

3.1.3 Iterative Design Process

Iteration is an essential part in UX design development. Even a seasoned designer is not skilled enough to achieve a perfect interface on the first try (Nielsen, 1993).

Nielsen (1993) suggests an iterative design process where the design is evaluated, iterated and then evaluated again in order to verify that the changes in the interface solves the users problems. Nielsen's approach to iterative usability design revolves around the idea of conducting multiple cycles of design, testing, and refinement to improve the overall user experience and enhance the usability of a product or service.

According to Nielsen, a traditional "waterfall" development process, where design and development occur in distinct sequential phases, often leads to usability issues that are discovered too late in the process, resulting in costly rework or suboptimal user experiences. In contrast, an iterative approach to usability design helps identify and address usability problems earlier in the development process.

Further it is suggested that at least two to three iterations are done but five to ten or even more iterations are preferred (Nielsen, 2011). These iterations can be combined with a parallel design where several alternative concepts are tried to find the most suitable one. These concepts are tested on users and then merged into a joint concept where insights from tests are combined.

3.1.4 Usability

Usability is a measurement of a system's ease-of-use (Nielsen, 1993). Usability is important because it ensures that a product, system, or interface is easy to learn, efficient to use, and satisfying for users. Good usability enhances user satisfaction, increases productivity, and reduces the risk of errors and frustration, ultimately contributing to the overall success of a product or service. Nielsen (1993) divides usability into five different quality components:

1. **Learnability** - How easy is it for users to accomplish basic tasks the first time they encounter the design?
2. **Efficiency** - Once users have learned the design, how quickly can they perform tasks?
3. **Memorability** - When users return to the design after a period of not using it, how easily can they reestablish proficiency?
4. **Errors** - How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
5. **Satisfaction** - How pleasant is it to use the design?

Nielsen (1994a) has also created ten heuristics that can serve as guidelines for designing user-friendly and intuitive interfaces:

1. **Visibility of system status** - The design should always keep users informed about what is going on, through appropriate feedback within a reasonable amount of time.
2. **Match between system and the real world** - The design should speak the users' language. Use words, phrases, and concepts familiar to the user, rather than internal jargon. Follow real-world conventions, making information appear in a natural and logical order.
3. **User control and freedom** - Users often perform actions by mistake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process.
4. **Consistency and standards** - Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions.
5. **Error prevention** - Good error messages are important, but the best designs carefully prevent problems from occurring in the first place. Either eliminate error-prone conditions, or check for them

and present users with a confirmation option before they commit to the action.

6. **Recognition rather than recall** - Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another. Information required to use the design (e.g. field labels or menu items) should be visible or easily retrievable when needed.

7. **Flexibility and efficiency of use** - Shortcuts hidden from novice users may speed up the interaction for the expert user so that the design can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

8. **Aesthetic and minimalist design** - Interfaces should not contain information that is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility.

9. **Help users recognize, diagnose, and recover from errors** - Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution.

10. **Help and documentation** - Its best if the system doesnt need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks.

Usability can be measured with several different methods. A theoretical evaluation of a design will not give quantifiable usability scores, but can indicate problems before testing a design with users. A practical evaluation with users will give qualitative data and/or quantifiable usability scores which can be used to improve shortcomings in the design.

3.2 User Research

A fundamental element in a user-centered design process is user research. This critical component aids designers in comprehending users, ensuring that the final product aligns with their needs and preferences. Ulrich and Eppinger (2012) emphasizes that establishing a high-quality information channel between users and product developers is a prerequisite for meeting the following criteria:

- Ensure that the product is focused on customer needs.
- Identify latent or hidden needs as well as explicit needs.
- Provide a fact base for justifying the product specifications.

- Create an archival record of the needs activity of the development process.
- Ensure that no critical customer need is missed or forgotten.
- Develop a common understanding of customer needs among members of the development team.

User research offers evidence-based insights into user needs, behaviors, and preferences, empowering designers to make informed decisions and create design solutions that cater to user goals. This approach reduces guesswork and assumptions, resulting in more effective and relevant design outcomes (Kuniavsky et al., 2012).

By identifying potential issues and areas for improvement early in the design process, user research gives designers a blueprint on how the product/service caters to user needs. Validating design decisions and assumptions with real users enables designers to ensure that their solutions correspond to user needs and market demands (Norman, 2013).

Furthermore, user research allows designers to cultivate a deep understanding of and empathy for their target audience, encompassing motivations, desires, frustrations, and contexts. This understanding facilitates the creation of user-centered designs that resonate with the audience and address their needs more effectively (Kuniavsky et al., 2012).

User research can also unveil insights into what users value and desire in a product or service, equipping designers to distinguish their solutions from competitors and establish unique values that appeal to their target market (Ulrich & Eppinger, 2012).

3.2.1 User Goals

A user goal is a specific objective that a user wants to achieve when interacting with a product, system, or service. These goals represent the desired outcomes or tasks that users seek to accomplish through their interaction with a design. Understanding user goals is an essential aspect of user-centered design, as it helps designers create solutions that directly address users' needs and facilitate the achievement of their objectives. By focusing on user goals, designers can prioritize features and functionalities that are most relevant and valuable to their target audience, ultimately leading to a more satisfying and effective user experience (Nielsen, 1994b).

In order to identify user goals, designers often engage in various user research methods, such as interviews, surveys, and observations.

3.2.2 Interviews

Interviews serve as a valuable tool in user research, offering a profound and intricate understanding of users' viewpoints, requirements, and experiences. As Kuniavsky et al. (2012) suggests, conducting interviews can significantly contribute to the design process, delivering insights that enable the creation of effective user-focused solutions.

A flexible interview format is beneficial as it permits researchers to modify their approach based on the individual they are conversing with and the context. This adaptability makes participants feel at ease, which in turn encourages them to share more honest and comprehensive information. The flexible format enables researchers to pursue intriguing topics that emerge during the interview, rather than adhering to a rigid set of questions, ultimately leading to a deeper understanding. Another advantage of this approach is its ability to accommodate various types of people, fostering a more inclusive research process. The capacity to adapt and adjust as needed during an interview enables researchers to collect more valuable and relevant information, ultimately resulting in improved designs and solutions.

3.2.3 Observations

Interviews can be combined with observations. When exploring a user's current situation and interaction with products, this is beneficial for insights into interaction and user behavior with the particular product or service. This situation enables the researcher to observe the user and define user goals related to the product. Observations are one of the main methods for gathering firsthand information and can depending on the desired outcome, be more or less structured (Hanington & Martin, 2019).

3.2.4 Think Aloud

Nielsen (2012) claims that thinking aloud is the #1 usability tool. When combining the method with a usability test, the researcher asks the participant to use the system while verbalizing their thoughts as they explore the interface, both in specific tasks as well as in free exploration.

By asking participants to vocalize their thoughts, researchers collect data that otherwise most probably would not have been collected. What a user thinks in each particular moment is not feasible to collect after a task is done. This type of data collection would inevitably be a summarization of the users thoughts and affected by how much the user remembers. Asking the user to think aloud remedies this shortcoming and provides data that has not (at least extensively) been filtered by the participant. Most users want to appear as intelligent, and the risk is that they stay silent until they have formulated their thoughts. This can be remedied by the researcher asking the user to speak. It is however important to balance the interaction with the user. Extensive prompting can lead to a biased test (Nielsen, 2012).

A think aloud test is preferably recorded to make it possible to go back and review the test if needed. If several researchers are conducting the test, notes can be taken to speed up the review.

3.2.5 Benchmarking

Benchmarking or competition benchmarking is a method for surveying the market and understanding how well existing products/services are applying to customer needs (Ullman, 2018). The goal of benchmarking is to gain insights into the strengths and weaknesses of the product being developed, and use this information to inform design decisions, enhance product features, and ultimately create a more competitive and successful fulfillment of user goals.

3.3 Analyzing User Research

The following sections involve the methods used to analyze the user research.

3.3.1 Affinity Diagramming

KJ analysis or Affinity Diagramming, is a collaborative technique used for organizing and synthesizing large amounts of qualitative data. Ideas, actions, observations and citations from interview/observation sessions are written down on post-it notes which are clustered into groups where the notes relate to each other. Originally developed by Jiro Kawakita and documented by Scupin (1997) this method is particularly useful for making sense of complex and unstructured information, identifying patterns, and uncovering insights that can inform the design process.

3.3.2 Personas

Personas are descriptions of users based on user research and are a great method for a team to create a common understanding of the users that are being designed for. It is generally built up of a description of a common or targeted user of the product and should be made realistic and believable. Descriptive features to include can be related to the project but also more general. Personas can work as a means for decision making for things such as what features to include or exclude (Harley, Aurora, 2015).

3.3.3 MoSCoW

The Moscow analysis is a method for prioritizing features for development. Developed by Clegg and Barker (1994) for use in rapid application development, this method divides features into the following categories:

- Must have: These are the critical and non-negotiable requirements that must be met for a project to be considered successful. Without these, the project will fail or the product will be unusable. Must-Have requirements often include essential functionalities, compliance with regulations, and safety features.
- Should-Have: These are important requirements that significantly contribute to the success of a project but are not strictly necessary for its basic functionality. Although not vital, Should-Have requirements are still high-priority, and their absence may result in reduced user satisfaction or effectiveness.
- Could-Have: These are nice-to-have requirements that can enhance a project's success or user satisfaction but are not considered essential. Could-Have re-

quirements are often lower-priority items that can be included if time and resources permit, but their absence will not significantly impact the overall success of the project.

- Won't-Have (or Would-Have): These are low-priority requirements that are not planned to be addressed in the current project or release but may be considered for future iterations. These requirements have the least impact on the success of the project and are not considered necessary at this stage.

By dividing into these categories, developers can decide where to put the main effort in designing and developing the product. The method is often combined with an agile and time frame methodology.

3.4 Prototyping

The upcoming section describes the methodologies employed during the design prototyping phase.

3.4.1 Braindrawing

Braindrawing is an idea generation method based on sketching (Wikberg Nilsson et al., 2015). It is a creative problem-solving and idea generation technique that uses visual representations, such as sketches or drawings, to facilitate communication, collaboration, and the exploration of ideas among team members. This technique is often used in design thinking, user experience design, and other fields that require innovative solutions and creative thinking.

A braindrawing session can be varied in several different ways but the essential component is that all team members start a sketch. After a specific amount of time the sketch is passed on to the next team member. The receiver continues the sketch, adding components, or uses the sketch as inspiration to start a new sketch. This continues for a set amount of rounds or until the team members deem the sketches complete. After the drawing session, the team members evaluate the sketches together.

3.4.2 Low Fidelity Prototyping

A sketch turns into a low fidelity (Lo-Fi) prototype as soon as it starts to transition from a set of ideas on paper, to a funneled and somewhat evaluated set of features (Buxton, 2007). Even if the investment in a Lo-Fi prototype is larger than in a sketch, they are far from a finished product. The distinction of a Lo-Fi prototype is not clear, however here it is interpreted as an artifact that is quick to create (but not to design) and lacks automated interaction. It can be created using various materials and formats, such as paper sketches, wireframes, storyboards, or simple digital mockups. The primary goal of a low-fidelity prototype is to facilitate quick iterations and testing design ideas and concepts before investing time and resources in creating high-fidelity prototypes or fully-functional products (Walker et al., 2002).

3.4.3 High Fidelity Prototyping

A high fidelity (Hi-Fi) prototype is a visualization that resembles the final product much closer compared to a Lo-Fi prototype. It is the last type of prototyping before moving on to developing the final product (Dam & Siang, 2020). The Hi-Fi prototype can be interacted with in a way that closely mimics the actual product experience. This helps in identifying potential usability issues and areas for improvement that may not be apparent in Lo-Fi prototypes. A Hi-Fi prototype also enables automation of interaction. Visual content can change instantly based on user input. A digital and automated prototype also enables supervised remote testing and automated remote testing with testing services such as Ballpark subsection 3.5.3 mentioned below.

Further, the Hi-Fi version communicates the actual design language to a participant. A participant will always think something subconsciously about the aesthetics of a prototype no matter on what level it is. A more polished version of a design should at least be better than the unpolished version in removing this obstruction while performing tests. When performing tests however, there is no difference in the amount of usability issues found whether a Lo-Fi or a Hi-Fi prototype is used (Walker et al., 2002).

Finally, a Hi-Fi prototype is an effective way to communicate a design to stakeholders (Dam & Siang, 2020). Not everyone involved in a development team is a designer and has the capability to "see beyond" the crude visuals of a Lo-Fi design.

3.4.4 App Prototyping with Figma

To create a Hi-Fi prototype, Figma was used. Figma is a web-based vector graphics editor and collaborative design tool used for creating user interfaces , user experience designs, prototypes, wireframes, and other visual materials (Figma.com, n.d.). The software allows real-time collaboration, which means multiple team members can work on a design simultaneously. Ability to "spotlight" another team is particularly useful when working remotely. It is a cloud-based tool, which means that designs are always up-to-date and accessible from any device with an internet connection. This makes it easy to share designs to other platforms as well as previewing the design on a mobile device while working on it.

There are readily available component libraries that enable designers to create reusable UI (user interface) elements, which can help maintain consistency and speed up the design process. Material design has such a component library, ensuring that the design keeps consistency with the outer world.

Figma has built-in prototyping features that allow designers to create interactive prototypes without needing third-party tools. This enables designers to test interactions with users and the design can closely resemble a real app.

Figma integrates with various other tools, such as project management and testing services, making it easier for designers to work seamlessly within their existing workflows. The prototype created in Figma prototype was used to facilitate both unsupervised testing subsection 3.5.3 and subsection 4.5.2 as well as supervised remote testing subsection 3.5.2 and subsection 4.5.1.

3.4.5 Material Design

Material Design is a design system and visual language created by Google in its first iteration in 2014. It provides guidelines, principles, and components for creating consistent, modern, and engaging user interfaces across different platforms, including Android, iOS, and web applications (Google, n.d.).

Key aspects include a grid-based layout system for visual consistency, a well-defined color palette for harmonious interfaces, and clear, legible, and scalable typography. Material Design also incorporates consistent iconography and pre-built UI components like buttons, cards, and navigation bars. It also involves guidelines for efficient information architecture and navigation and states that in an app users have the ability to navigate in three directions: laterally, forward, and backward. Lateral navigation refers to moving between screens at the same hierarchy level and should be possible from the top level of the app's hierarchy. Forward navigation means accessing content deeper in the app's hierarchy by going downward in the app. Reverse means moving through recent screen history or upwards in the hierarchy.

Material Design emphasizes meaningful motion and interaction, ensuring context and seamless flow between interface parts. By following Material Design guidelines, designers and developers can create visually appealing, intuitive interfaces for a seamless user experience across platforms and devices.

3.5 Evaluating Design

In the following sections, the approaches utilized when evaluating the design are outlined.

3.5.1 Prototype User Testing

There are several reasons for testing a design. Cooper et al. (2014) argues that involving users in the testing process is essential in order to create a product that fulfills user goals. Designers often make assumptions about users' needs, preferences, and behaviors. User testing helps validate these assumptions by revealing whether the design meets the expectations of the target users, addressing their needs, and providing a satisfying user experience.

Testing prototypes with real users helps uncover usability issues, such as confusing navigation, unclear labels, or unanticipated user interactions. Testing also enables designers to empathize with their target users by observing their struggles, frustrations, and successes when interacting with the prototype. This empathy helps designers to make more informed and user-centered design decisions, ultimately leading to a more successful product.

Prototype testing can be conducted in several ways. In person testing, supervised remote testing (see subsection 3.5.2) via internet and unsupervised remote (see subsection 3.5.3) via testing services are some examples (Usabilityhub, n.d.). Each of these methods have their benefits and drawbacks. In person testing and supervised remote testing has the benefit of the researcher being able to talk to the participant while testing. Questions can be asked (usually in a non leading way) and clues can be given if the participant needs them. Furthermore the participant can be observed while testing and the researcher can draw conclusions about how the participant feels about the specific feature or in general while interacting. These tests tend to last longer than other methods and the participant needs to be available and scheduled for a test.

Unsupervised remote testing via services (such as Ballpark mentioned below subsection 3.5.3) has the benefit that users can choose to do the test when it suits them. The largest drawback is that the researchers can not interact with the participant while testing and subtleties can not be observed.

3.5.2 Supervised Remote Testing

Conducting supervised users tests with a prototype is achievable over the internet. A prototype in a design tool can be previewed and interacted within a web browser. A researcher can share the prototype and observe and speak to the respondent with a video call over the internet, while the participant shares the screen. The test can contain a set of tasks to be completed or a free roam test where the participant is free to explore the prototype. A strength with a supervised test is that the researcher can use the techniques mentioned in section 3.2 to get insight into the participants thoughts. This is a key difference compared to unsupervised testing.

3.5.3 Unsupervised Remote Testing

Ballpark is a service for prototype testing and surveys online (Ballpark, n.d.). It allows designers and researchers to validate their designs, prototypes, and concepts with real users quickly and efficiently. Ballpark integrates with popular design tools like Figma, making it easy to turn design projects into interactive user tests.

With Ballpark, the researchers can set up tasks for users to complete within their prototype, helping in evaluating how well the design addresses specific user needs or goals. It is possible to collect both quantitative (e.g., task success rates, time spent on tasks) and qualitative data (e.g., written feedback from users). Usability metrics, such as completion rates, time on task, and misclick rates, as well as heat maps are collected.

The researcher can develop their testing scheme according to their preferences. Traditional survey questions such as gender and age can be combined with prototype testing with metrics. There is no need to develop a separate form survey as this can be incorporated in the test in Ballpark.

3.5.4 Semantic Word Scale

A semantic word scale or a semantic differential word scale is used to measure how users feel about a product, their attitudes, opinions or perceptions of the product (Wikström, 2002). The word scale can be done as a survey and each question contains two opposing pairs. An example of a pair is "easy to use" and "hard to use". These labels are put on each side of a grading scale and the respondent is asked to mark where on the line between the word pairs their answer is. An advantage of a semantic word scale is that it can measure a product without giving it an explicit score. It is rather a balancing act between the two opposing pairs.

4

Design Process

This chapter presents the design process of the project and the included phases. In order to guide the design process, the following research questions were formulated.

Guiding Research Questions

1. What information and interaction is a homeowner expecting/benefiting from when enrolled in a VPP and how can this be presented in a way that provides an attractive user experience?

2. How can unfamiliar and complicated concepts regarding electricity be presented in an understandable and engaging fashion? Examples are how to communicate power grid frequency, electricity units (kWh/kW/kWp etc.) and why they matter to the user.

3. How can electricity information be presented to encourage sustainable behavior in a residential setting?

4.1 Design Phases

The project was divided into four phases, see Figure 4.1. These phases were decided with consideration of HCD, RtD and iterative design. Each phase was set up with preliminary activities and goals. The phases are:

- Preparation
- Explore
- Build
- Test - rebuild

The following sections describe each phase and its contents.

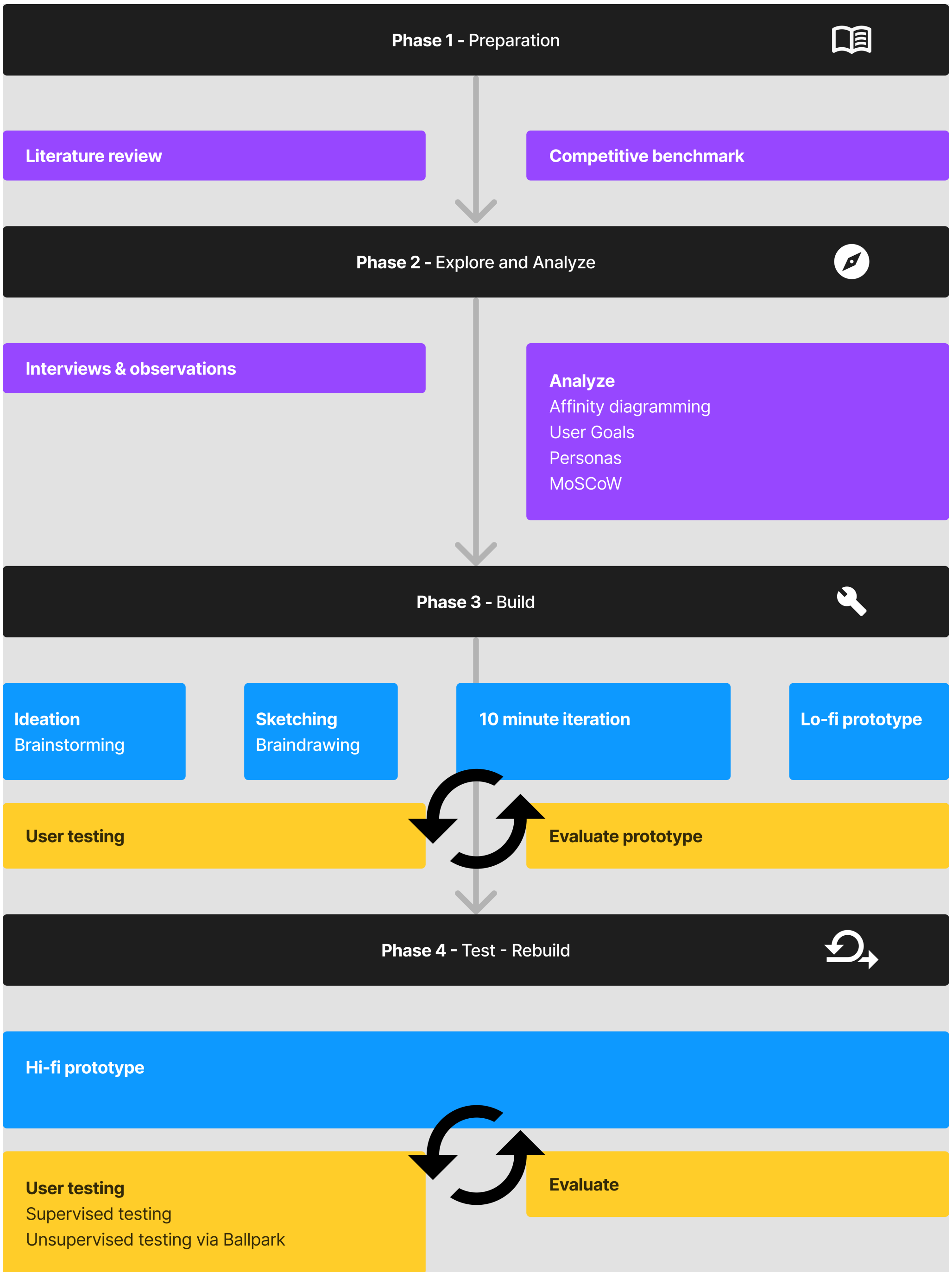

Figure 4.1: Visualization of the design process and its phases.

4.2 Preparation

The preparation phase aimed to discover what competitors there are on the market for solar and battery monitoring software in residential use. A literature study on how to communicate quantities of energy was also performed. The goal of the phase was to get a comprehensive market overview, as well as guidelines for communicating quantities of energy.

Further, a study was performed with the aim to understand the energy system and market in order to be able to design a solution that takes complex aspects into account. The study was needed for proficient communication with users and the company. The knowledge is presented in section 2.1, The Nordic Power Grid.

4.3 Explore and Analyze

During the explore and analyze phase, the goal was to define and specify user goals and needs. This was done by conducting user research in the form of interviews and observations. The results were synthesized with an affinity diagram and prioritized with a MoSCoW analysis.

4.3.1 Interviews and Observations

With the aim of understanding user goals and motivations, 6 interviews of about an hour each, were held with participants listed in Table 4.1. The participants were found through Facebook groups relating to PV-production and home batteries and through CheckWatt's customer base. The interview consisted of general open-ended questions relating to energy monitoring apps, as can be found in appendix A.1, and during the interviews the interviewee was asked to share their screen on both mobile and desktop devices. They were asked to show all of their energy monitoring systems that they use and how they use them. If they were a customer of CheckWatt more focus was put on EIB. This let the researchers observe which features were of significance and what goals and motivations users had when using the different systems. The interviews were analyzed and user goals as well as motivations/quotes were collected and written down on sticky notes in FigJam subsection 4.4.1. The sticky notes were then sorted with the help of an Affinity diagram.

Table 4.1: Interviewees

Gender	**Age**	**CheckWatt customer**
Male	50	No
Male	35	No
Male	61	Yes
Male	50	Yes
Male	62	No, but soon
Male	45	Yes

4.3.2 Affinity Diagramming

The quotes, motivations, and goals gathered from interviews and observations were organized into categories based on identifiable connections. A list of requirements were created from this and later organized with a MoSCoW analysis.

4.3.3 MoSCoW Analysis

From the Affinity diagram a requirement specification was extracted which states the found user goals for each found category. The user goals were then translated into a requirement specification on which a MoSCoW analysis was performed and each item on the list was given an order of priority. The order of priority made it possible to better sort out which of the goals were of most importance and where the effort should be put.

In order to prioritize the features, they were mapped to the following criteria.

- **Unique Selling Point** - There exists several apps for monitoring electricity consumption and production. If the feature was not present in competitive apps and fulfilled a user goal, it was deemed unique and increased the prioritization.
- **Presence in other apps** - If the feature was present in a majority of the competitive apps, it increased the prioritization as users would expect the feature as a set of basic functionalities.
- **Request from users** - Some features were expressed by several of the participants in the interviews and observations 4.3.1. If the feature to be prioritized catered to this need, it improved the prioritization.
- **Technical feasibility** - There are limitations to what is reasonably easy to implement in software. Features were considered with these limitations in mind. If a feature was hard to implement in the future, the prioritization was decreased.
- **What CheckWatt wants to do** - CheckWatt has a strategic plan and ideas about which direction the company wants to choose in the future. The direction and single features were discussed at several occasions. If a feature was not in line with the company's direction or plan, the prioritization was decreased.

4.4 Build

The goal of the build phase was to create a low fidelity prototype satisfying the user needs and to prepare for further and in depth prototype testing. Results from the phase are described in chapter 7 together with results from the Test - rebuild (section 4.5) phase.

4.4.1 Ideation

The phase started out with braindrawing subsection 3.4.1 as a main method of ideation. Inspiration was taken from competitors in the benchmarking subsection 3.2.5. Which features to turn into sketches were selected from the user goals section 6.2 formulated in the explore and analyze phase. No strict braindrawing sessions were held. One of the group members rather selected a feature and started sketching. The other group member then looked at the sketch and both participants reasoned about the concept and how it fulfilled the user goal. The braindrawing was held in FigJam (a part of Figma), an infinite canvas digital whiteboard tool that facilitates sketching both with a digital pen as well as a computer. The braindrawing was done in conjunction with the ten minute iteration described in the section below.

4.4.2 Ten Minute Iteration

This project has used what the project's designers would call ten minute iterations. The name suggests that each iteration is done in ten minutes. Sometimes this is true, but sometimes it lasts a bit shorter or a bit longer. The name rather highlights that each iteration is done quickly.

The process started with hand sketching a static user interface in a quick and dirty manner but with careful consideration to stated user goals. Embracing speed gave the designers a challenge to think quickly and creatively, which generated a wide range of ideas and design improvements in a short time span. The sketch was then tested on students for comprehension of information. It also gave the designers a chance to get user feedback and to identify areas for improvement. The researcher asked questions and the respondents were asked to reason around the sketch. With the insights from the quick test, the sketch was revised or completely redrawn in order to improve fulfillment of user goals and comprehension. The new sketch was then tested on another person in order to verify that changes made were an improvement. These rapid iterations reduced the risk of getting trapped in too much reasoning of design choices and gave agility to the process. The cycle was repeated several times, and as ideas and features were verified the effectiveness of the prototype. Testing with Lo-Fi prototypes gave useful insights and was done until the designers deemed it necessary to create a Hi-Fi prototype to facilitate higher level testing. In the "sketching ideas" sections of chapter 7, outtakes from the process are shown in the form of sketches that evolved into a prototype.

4.5 Test - Rebuild

The end goal of this phase was to create a Hi-Fi prototype and perform user tests to verify the design. This phase was, in line with the planning, the longest running phase in the design process. During this phase, the design evolved from a Lo-Fi prototype, to a Hi-Fi prototype. The prototype facilitated both unsupervised as well as supervised testing. The results are described in chapter 7 and the following methods were used.

4.5.1 Supervised Remote Testing

Five supervised tests were held over the internet in a video call. Some persons were reused from the interviews and observations (Table 4.1) and two new were recruited. Participants were scheduled beforehand and the tests lasted from 45 to 60 minutes. The participants were given access to the digital Hi-Fi prototype and shared their screen during the test. A scenario together with six sequential tasks were given. The participants were asked to think aloud while performing the tasks. A complete set of tasks can be seen in appendix B.1. A list of participants is presented in Table 4.2. After the test, the participant was asked to take a short survey with a semantic word scale. The purpose of the survey was to measure how the participants perceived aspects like gender neutrality and language of the prototype. The word scale together with results are in appendix B.2.

Table 4.2: Participants in supervised remote testing

Gender	**Age**	**CheckWatt customer**
Male	39	No
Male	35	No
Male	50	Yes
Male	51	No
Female	38	No

4.5.2 Unsupervised Remote Resting via Ballpark

A request to take a Ballpark test (3.5.3) was shared in a social media group dedicated to CheckWatt residential customers. Initial response was slow, but after some direct requests in private messages response increased. The test was also shared further by participants to other customers, not a part of the group. 16 users presented in Table 4.3, took the test before it was closed after 30 days. The full test can be viewed in appendix B.3 and the full results from the test in appendix B.4.

Table 4.3: Participants in unsupervised remote testing

Gender	PV owner	Knowledge of ancillary services
Male	No	Yes, a little bit
Male	No	Yes, pretty well
Male	Yes	Yes, pretty well
Male	Yes	Yes, pretty well
Male	Yes	Yes, pretty well
Male	No	Yes, a little bit
Male	Yes	Yes, a little bit
Male	Yes	Yes, pretty well
Male	Yes	Yes, pretty well
Male	Yes	Yes, pretty well
Male	Yes	Yes, pretty well
Female	No	No
Female	Yes	No
Female	Yes	No
Female	No	No
Female	No	No

The test consisted of different types of tasks. These are listed below.

- Standard survey questions - 6 questions
- Interactive tasks - 3 tasks
- Comprehension questions - 4 questions
- Rating - 5 ratings
- Free roam

The test began with standard survey questions to collect demographic data. These questions asked the respondent about their gender, if they owned solar panels and/or a home battery, their knowledge of ancillary services and finally if they are connected to a VPP.

The interactive tasks intended to test interaction with the prototype. A start screen and a goal screen was defined in Ballpark. The respondents were then given a scenario and a task where they were required to find some piece of information within the prototype. When the respondent hit the goal screen, the task ended automatically. If the respondent could not solve the task, they could use the "end task" button to skip the task. Example can be seen in Figure 4.2.

The comprehension questions intended to test whether the respondent understood the information presented or not. Four different animations were presented in the test and the respondents were given multiple choices or a text field to answer the questions.

Five different rating tasks were given. These ratings aimed to mainly answer if the respondent found the presented feature usable or not. The ratings were always combined with the possibility to provide a free text answer.

Finally, the respondents were given a free roam of the prototype. In this step, they could explore the prototype for as long as they wanted. No specific tasks were given and no goal screen was defined. After ending the task, they were given the option to provide their thoughts in a free text field.

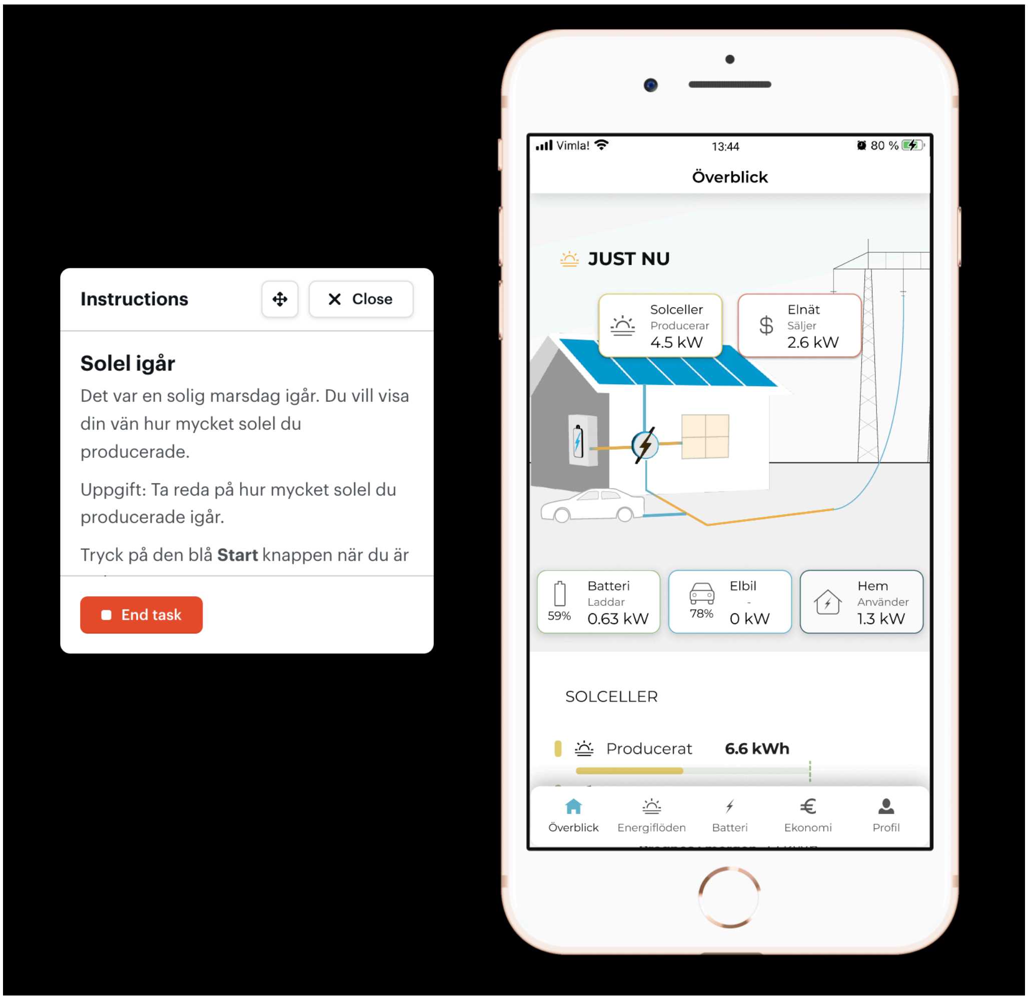

Figure 4.2: Excerpt of unsupervised test

4.6 Finalize

The final step was to take action on the results from user testing. These results were used to finalize the design in the scope of this thesis. In areas where the design was successful, no changes or small changes were made. In areas where the design had shortcomings, the prototype was redesigned to increase comprehension and fulfillment of user goals. The final version of the prototype is presented in chapter 8.

5

Results: Preparation Phase

This chapter begins the results part of this thesis and presents the results from the preparation phase. It contains the benchmark results as well as the results and conclusion from the literature study about communicating energy.

5.1 Benchmark

The following section outlines the results from the benchmark.

5.1.1 Competitors

An extensive benchmark was created by finding various energy monitoring apps and web platforms. 21 mobile applications and 14 desktop interfaces were investigated. Images of benchmark is not included in the thesis because of copyright. The benchmark worked as a means to better understand aspects and functionalities of the energy monitoring apps currently on the market. It also aided the later development stages as current apps were compared to the found user goals and needs and how well their functionality would satisfy said goals and needs.

These interfaces fulfill user goals to different extents. None of the interfaces fulfill all of the user goals formulated in the MoSCoW analysis, section 6.2. The following list contain problems found in the competitor benchmark.

- Mix between high and low level content
- No adaptation for the Nordic market
- Ancillary services are not taken into account

There is a mix between very high level technical content and low level technical content. It can be mixed on the same page and requires that the user has enough knowledge to filter out the information that is relevant to them.

Interfaces are not adapted for the Nordic market. There is for instance no support for spot prices on Nord Pool. As PV manufacturers often are global and the Nordic countries has quite a low population number, compared to other countries, this is understandable.

Ancillary services in the residential sector is a new phenomena and no manufacturers except the German manufacturer Sonnen has taken them into account. Since performing ancillary services is surrounded by legislation as well as technical directives, the services performed by a Sonnen system are not available in the Nordic countries.

5.1.2 Current Interface, EnergyInBalance

When being a CheckWatt customer you receive access to the visualization tool EnergyInBalance (EIB), a web based interface created for desktop use, showing information such as energy production and consumption. The landing page Figure 5.1 gives the user an overview of components in one's facility. There are two additional pages for more granular information about production and consumption. Two more pages are dedicated to visualizations regarding the battery, one showing energy and the other revenue. There is also the possibility to export all data. EIB is also available as a mobile app, which is however outdated and has not been updated for 4 years. It was intended to mainly cater to the needs of residential solar production, but with the current business model the app is no longer as relevant and not an app that CheckWatt encourages users to download.

As part of the benchmark and to better understand the current interface and its strengths and shortcomings, interviews and observations were held where users would interact with their system, see section 3.2.

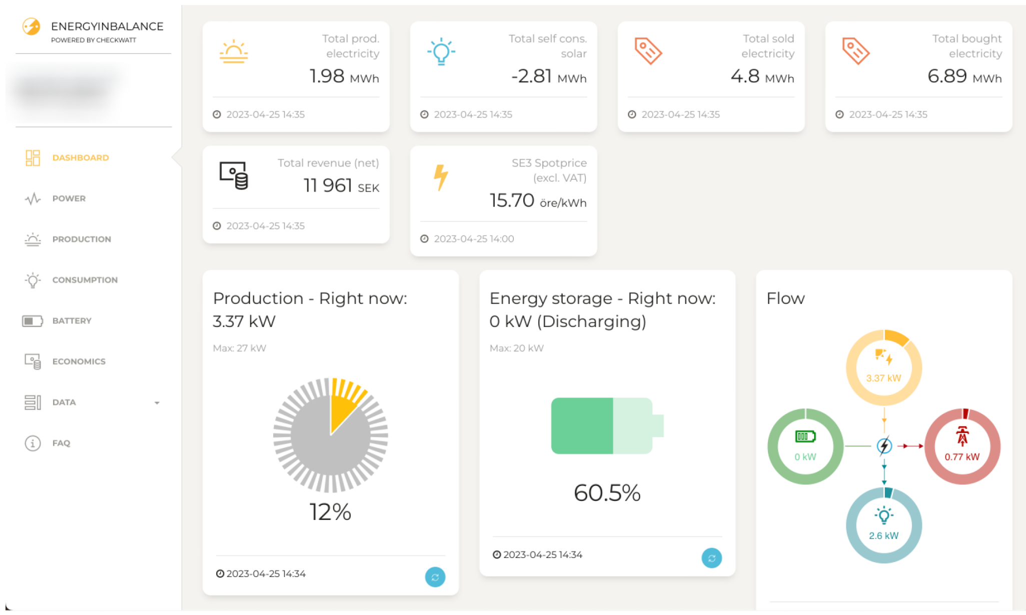

Figure 5.1: Landing page, Energy in Balance

EIB has, as previously stated, been developed mainly for web and the responsiveness of the site is creating legibility issues, especially when scaling for mobile devices - as can be seen in Figure 5.2. This was also later found to be a pain point among users and a mobile app was a sought after feature, both from the users and from the company.

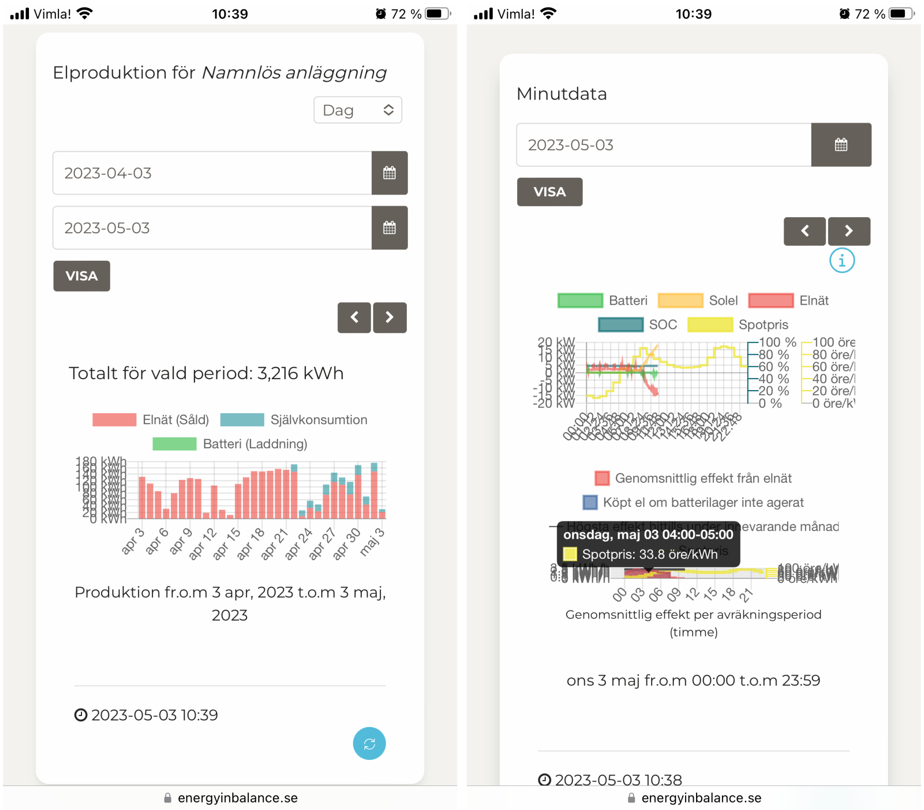

Figure 5.2: Mobile version of Energy in Balance

5.2 How to Communicate Energy

A short literature study was performed in order to find best practices for communicating quantities of energy in a tangible manner. Search terms used were, communicating energy, communicating kWh, tangible power, communication of intangible concepts and similar search terms related to energy. The previous research proved to be sparse in the area. Two of the most usable studies are presented below.

El Gohary et al. (2022) studied how people understand demand based tariffs and their conceptual grasp of power. They found that the respondents had struggled to distinguish between power and energy. They also found that exposure to demand based tariffs increased the knowledge of these concepts and that their understanding of the difference between power and energy increased in this scenario.

In the study "What can you do with 100 kWh", Hedin and Luis Zapico (2018) found that training people on energy usage and energy quantities had long lasting effects. A benchmark study was performed followed by an intervention. The intervention was training for 10 minutes in a web interface (https://kilowh.at/) where user could compare energy quantities linked to an entity such as a fridge or a led lamp. Immediately after the intervention, a "huge" effect was observed with a size of 2,25 Cohen's d. Six months after the study, this effect had been reduced to 0,93, but still deemed as "large" by the authors.

The conclusion from the literature study is that it is best to not abstract energy quantities in other concepts. As electricity production is transitioning towards a larger quantity of RES, there will probably be larger fluctuations in prices. This combined with the need for improved energy efficiency will result in a better awareness and understanding of energy quantities in general. From interviews and observations, it is also concluded that persons with solar panels generally have a better understanding of energy quantities.

The decision to not extensively abstract energy quantities in the design was taken with regards to the above reasoning. There are however cases where a translation helps the user achieve his/her goal. One such example is in the case of owning an electric car. The amount of energy stored in the car is in several cases better to communicate as range, rather than a percentage or energy quantity. Since a car enables its user to transport themselves over large distances, communicating the state of charge in terms of range adheres to the user goal of transportation.

6

Results: Explore and Analyze Phase

This chapter presents the results from the phase Explore and Analyze and lists the found user goals.

6.1 Affinity Diagramming

The cards created with quotes, motivations and goals from the analyzed transcriptions of interviews were sorted into eight separate groups. These were then sorted in subcategories with subheaders to better structure the needs and motivations, as can be seen in Figure 6.1. The main categories found were economy, battery, energy consumption, solar panels, electricity price, sustainability, interactivity, revenue.

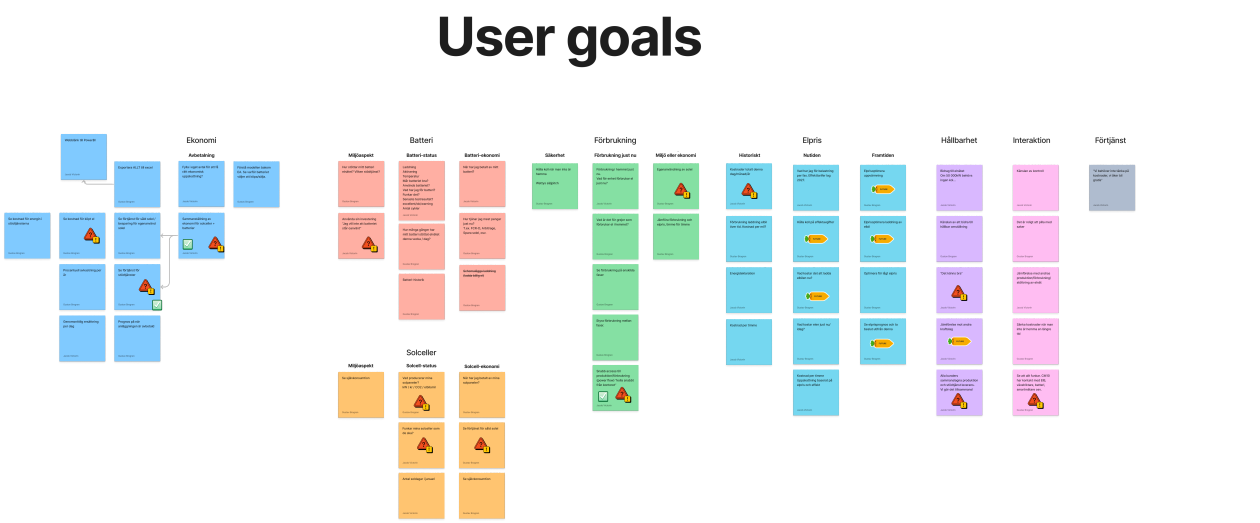

Figure 6.1: Results of affinity diagramming

6.2 User Goals - Requirement Specification MoSCoW

With regards to the criteria stated in subsection 4.3.3, the following features and user goals are some deemed necessary for a satisfactory end product (full MoSCoW see appendix C):

Device

1. Cater for mobile as well as desktop and tablet devices

Solar Panels

2. Ability to quickly access current flow of energy eg. current production and consumption
3. Ability to see historic production and consumption
4. Ability to see level of self consumption
5. Ability to indicate whether solar panels are functioning properly or not
6. Ability to see economy related to solar panels

Energy Consumption

7. Ability to see energy consumed and cost of usage
8. Ability to see solar energy consumed
9. Ability to plan for optimal time to consume electricity

Battery

10. Ability to see status of battery eg. state of charge
11. Ability to see battery service setting eg. type of ancillary service
12. Ability to see battery activity with regards to ancillary services and Currently
13. Ability to see that the battery is performing work

Economy

14. Ability to see income generated by facility and from ancillary services
15. Ability to see a summary of costs and income
16. Ability to see a forecast of return on investment

Sustainability

17. Ability to see facility in regards to sustainability
18. Ability to make decisions based on the most sustainable outcome

6.3 Personas

To get a joint understanding of the users and to better empathize, personas were created. This was to benefit from specific examples rather than from abstract concepts and general statements in the development process. The personas were part of the design process and aided in designing for the actual users. Four personas, two male and two female, were created to capture a wide range of users, example in Figure 6.2 and full version in Appendix D. A template found in FigJam created a basis of information deemed useful about the persona for the development process. The description written for the personas were related to their involvement in solar panels and home batteries as well as general energy management and based on the interviews held as well as research paper. Due to under-representation of women in the user studies performed, one particular paper was used called "Do they pass the woman test?", that facilitated a basis for the development of personas. In the study the researchers "shows how women at different touch points in the process of buying and having solar panels both navigate and negotiate an ongoing gendering of this technology" (Håkansson et al., 2022).

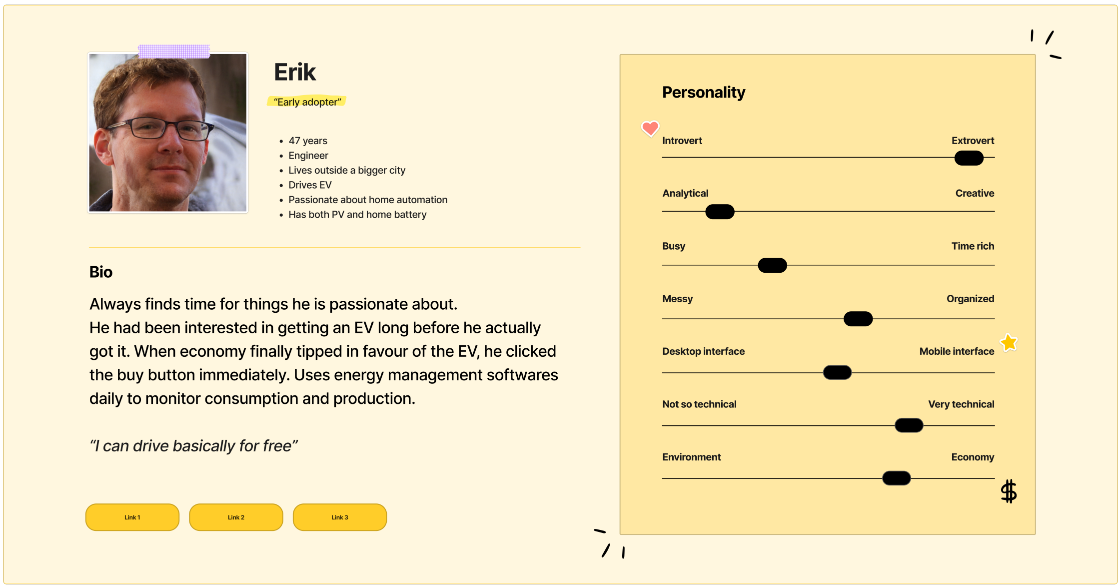

Figure 6.2: Excerpt of persona. Full version in appendix D

7

Results: Build Phase & Test - Rebuild Phase

This chapter describes the results from the *build* phase and the *test - rebuild* phase. These results are combined and each section of the prototype is described from sketching ideas to the interactive prototype and finally the results from user testing and how the user goals are fulfilled. Note that several user goals can be fulfilled by one feature, the main user goal is listed in the feature description.

7.1 Överblick - Overview

The *överblick* (overview) page is meant to work as a page that could cover most of the daily interactions the user has and fulfill most of the user's simple daily goals. The goal was to create a short summary of what was deemed the most important functionalities.

7.1.1 Sketching Ideas

What was found important from the user research to involve on the overview page was user goal 2 *Ability to quickly access current flow of energy eg. current production and consumption*. It was also found that the energy flow chart in the current interface EIB was difficult to interpret. So in order to satisfy the user's need for quick access to current status, different types of energy flow charts were sketched - examples can be seen at the top of Figure 7.1. All of the interviewees connected to Currently checked their income of ancillary services on a daily basis, user goal 14, *Ability to see income generated by facility and from ancillary services*. This therefore had a central role in all of the sketched layouts of the overview page.

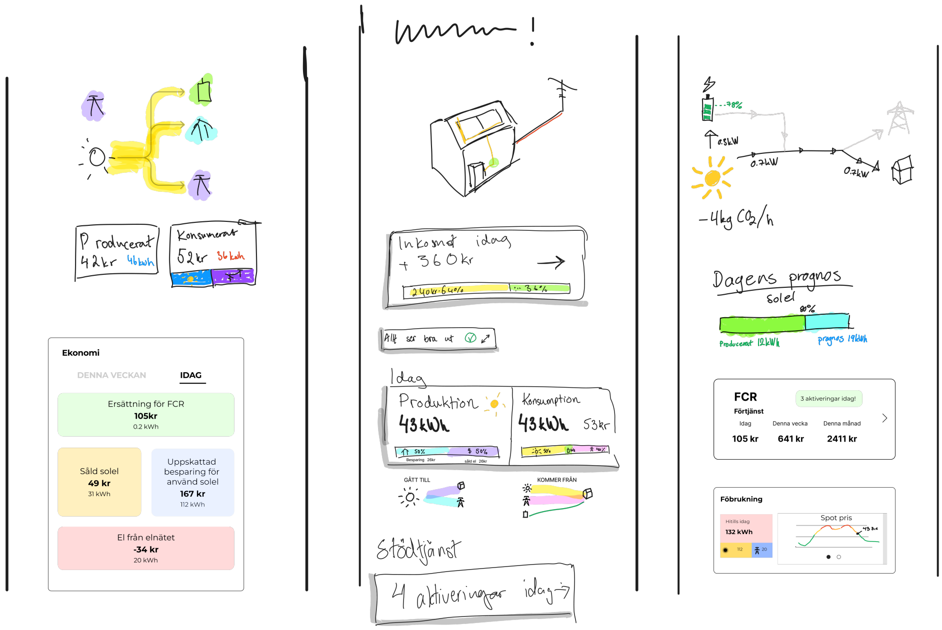

Figure 7.1: Overview page sketches

7.1.2 Interactive Hi-Fi Prototype

This page (Figure 7.2) starts with an overview of the energy flow which is visualized with an image of all involved flows with information in each container, facilitating a match between the system and the real world. An animation of the flow was created to show the direction of the energy. To further communicate the direction, descriptive text in each container was added. When tapping the container more information is presented, to further make the system status visible.

The next widget on the page is of total solar production as well as the forecast amount of produced solar electricity. This is visualized in a horizontal bar graph where the total amount of the forecast is 100 % width colored green and as the production goes on during the day the bar fills up with yellow (produced solar).

The battery widget (Figure 7.2) gives basic information about the status as well as indicating what the battery is set to do in regards to the VPP (in the image the battery is set to FCR-D). Below this, the number of FCR-D contributions (*insatser*) is shown along with the current grid frequency. This is to create a better understanding of Currently and make the users connection to the grid frequency stronger in order to understand the value that they are creating. The wording contribution is not an adopted technical term. It was carefully chosen to indicate the value of ancillary services from a systems perspective, rather than using the established technical term, activation.

The last part (Figure 7.2) is a section about economy where the income from ancillary services as well as sold electricity is stated. A graph showing the electricity spot price traded on Nord Pool can be found further down which shows the prices for today as well as for tomorrow. For a quicker interaction the max and min price is shown at all times. This widget gives the user a way to better plan for optimal time of energy consumption adhering to user goal 9 *Ability to plan for optimal time to consume electricity.*

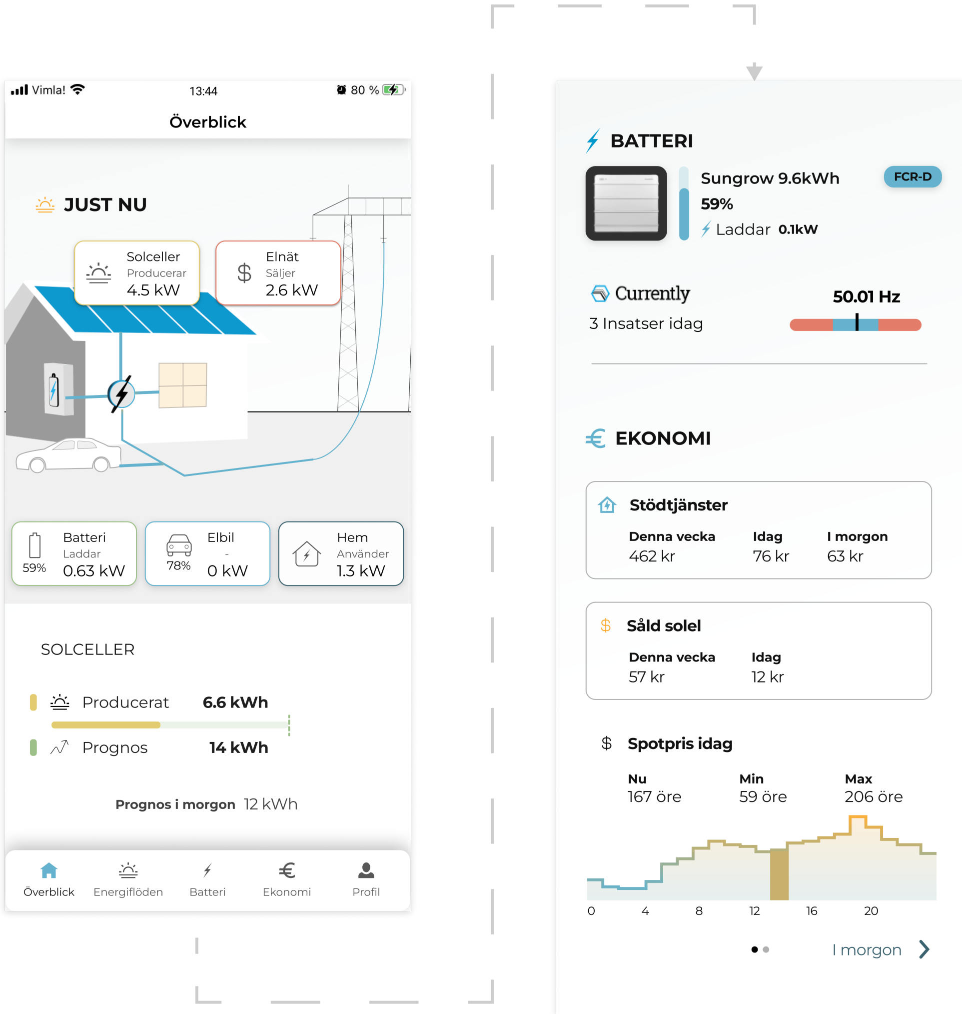

Figure 7.2: Home screen. The page is scrollable but here divided

7.1.3 Learnings from Testing

The overview page had a majority of positive feedback in the user testing. This is the conclusion from both the supervised and the unsupervised tests. In the supervised tests several participants thought the information presented is what they would like to see on a start page in the app. It contains enough information to satisfy the user goal 2 *Ability to quickly access current flow of energy eg. current production and consumption.* In the unsupervised testing a test score of 5,38 (median 5) out of 7 was achieved when users were presented with the visualization Figure 7.2 and asked "What do you think about the overview of the energy flow". When users were asked to answer in a multiple choice question what each entity in the visualization did, 14 out of 16 answers were completely correct. One user missed what type of energy the home was consuming and one user thought the battery was discharging instead of charging.

An improvement would be to increase the visibility of certain elements. Some users reported that the lines indicating energy flow were hard to see. These lines could be made thicker in order to take more visual space and increase visual clarity. Other elements such as the house also got some attention in it being a bit unclear. The design was done with regard to the graphic profile of the company. These results indicate that the graphic profile might not be fully satisfying in this type of design.

After users saw the possibility to switch between power and money (kWh/kr) in the Energy flow page, they mentioned that it would be usable to also have this switch on the overview page.

Finally, some users tried to click the *ekonomi* (economy) card. This element was not clickable by design and this could be made clearer.

7.2 Energiflöden - Energy flow

The idea behind the *Energiflöden* (energy flow) page is to guide the user through their consumption and production of energy, with the PV-production as a reference point for each of the following graphs.

7.2.1 Sketching Ideas

With the aim of fulfilling user goal 9 *Ability to plan for optimal time to consume electricity* and 5 *Ability to indicate whether solar panels are functioning properly or not* the forecast became central for the first graph showing the PV-production. Too big of a deviation from the forecast would give the user an indication of something faulty. If working as they should, the prognosis will give the user a possibility to plan their day in regards to if the user wants to sell the produced electricity or self consume it. There are multiple forecasts for solar panels available on the market and they are generally based on different meteorological data as well as data about the solar panels such as panel tilt and panel direction. The sketches of this page can be seen in (Figure 7.3).

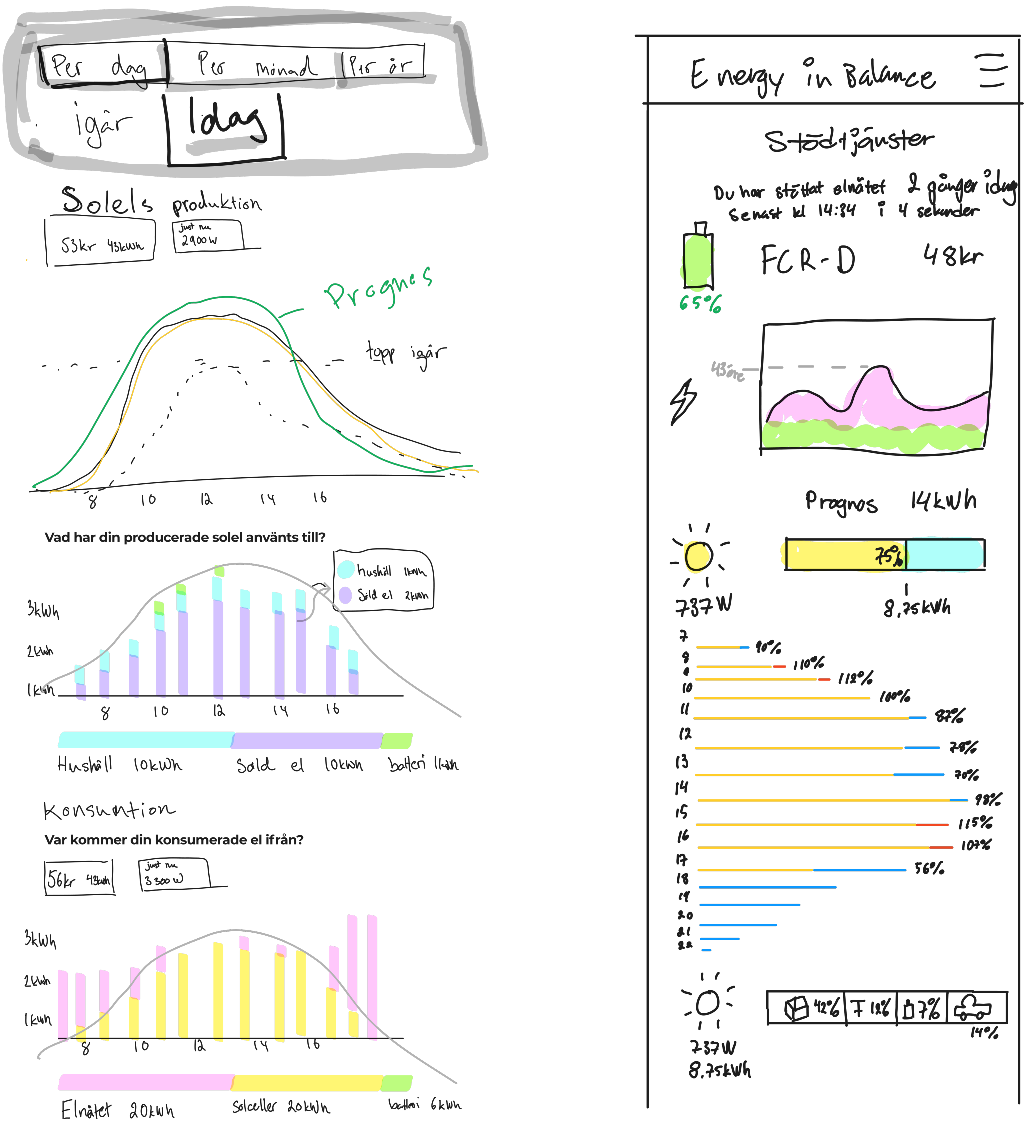

Figure 7.3: Sketches of energy flow page

7.2.2 Interactive Hi-Fi Prototype

The page starts with solar production compared to the forecast shown in Figure 7.4. A widget showing the deviation in percentage from the forecast was placed beneath the graph which would allow the user to see how well the system has been performing throughout the day in comparison to the forecast. This to further cater for user goal 5 *Ability to indicate whether solar panels are functioning properly or not.* To understand from what source and for what electricity has been used, graphs related to the energy flow were placed on a scrolling page, instead of separating them. This allows for placing the curve of the solar production as a common denominator in all graphs, in line with the usability heuristic of recognition rather than recalling. This was also a way of telling a story about the consumption and production, by always being able to compare it to solar production. To tell a story and to guide the user through the interaction, the copy for the headers used were written as questions that were then answered in the graphs such as "What has your solar energy been used for?".

The following graph shows what the solar energy has been used for divided into Home, Sold electricity, Charging battery, Charging EV, as well as stating how much of the produced electricity has been self-consumed. The graph *Förbrukning* (Usage) then goes on to state the total consumption divided up in the used energy sources (solar, battery discharge, grid). The following graph, *Hemmets elanvändning* (House usage) goes into finer details of what electricity was actually used for. The last graph also allows the user choose what to display (adhering to usability heuristic user control and freedom) and to include the curve for the Spot-price in order to fulfill user goal 18 *Ability to make decisions based on the most sustainable outcome*. This makes it possible to see when the demand of electricity is high compared to one's solar production as well as complete consumption. To further cater for the user goal 7 *Ability to see energy consumed and cost of usage*, a toggle has been placed in most graphs that allows the user to switch between Swedish crowns and energy. The calculation of money is done with the current electricity spot price and includes all fees and taxes making it accurate for most users. However, users with fixed rate contracts should be able to specify this in the settings to be able to get accurate values as well.

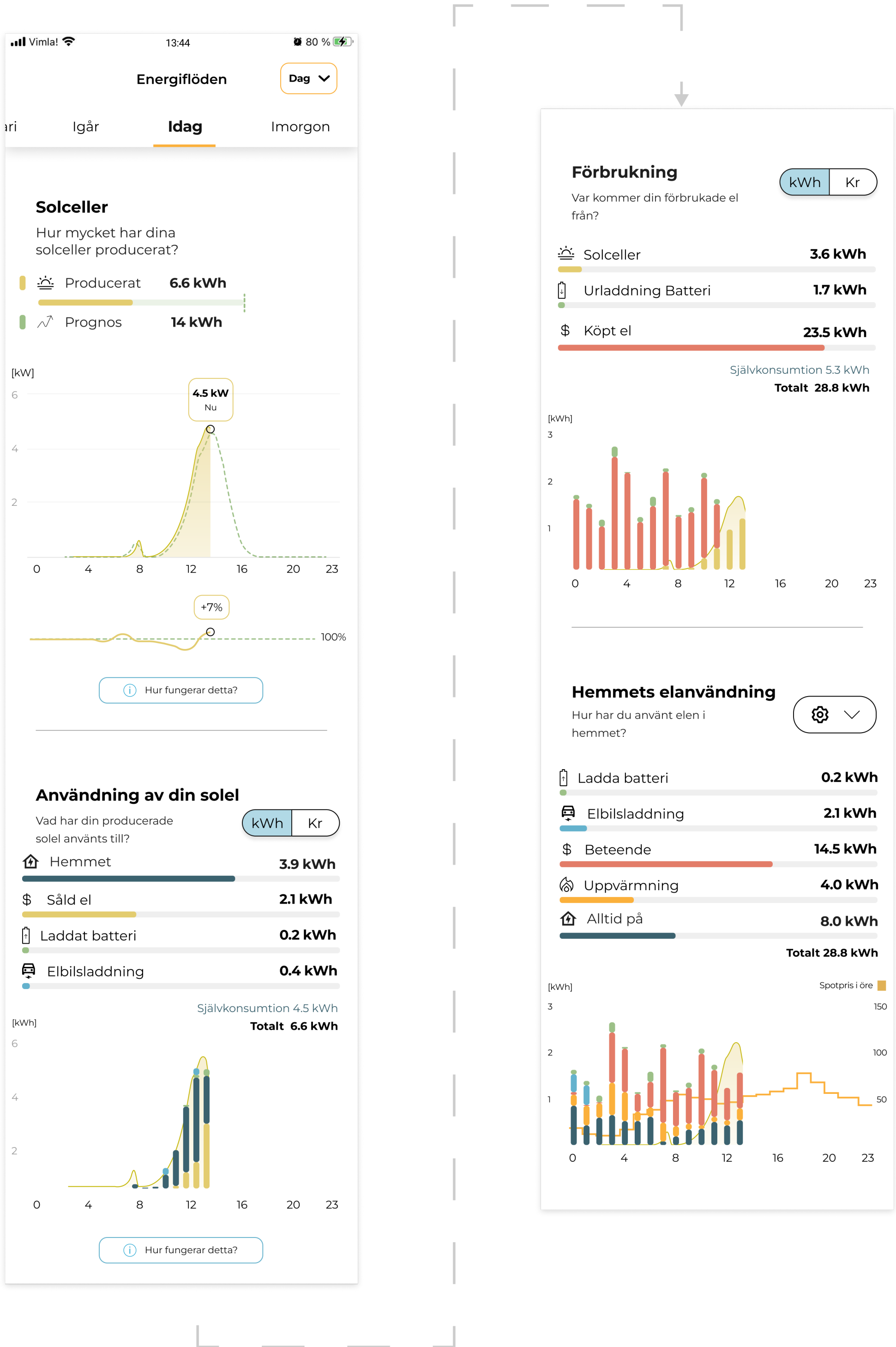

Figure 7.4: Energy flow page. The page is scrollable but here divided into two images. Bottom navigation is removed. To the left, replay passive. To the right, replay active.

7.2.3 Learnings from Testing

The outline of the energy flow page was appreciated by users and the scrolling page was found to be easy to navigate through. Starting from the top, the forecast was a graspable concept for most users and the graph showing the comparison between the forecast and actual production had a high learnability rate. In the unsupervised remote test 12/16 had the correct answer when asked to explain the graph. However, what seemed to be lacking was an explanation of how the forecast model works. Several users were questioning what aspects were taken into account for the creation of the forecast and felt disbelief in the forecast, mostly from experience from other apps where the feature is not as elaborate. In the supervised test the forecast model was explained on request and after explanation the respondents understood it and thought the feature was useful. This was not possible in the unsupervised test and the conclusion is that the design could better explain how the model works. One option would be to explain when the user starts using the app and inputs needed parameters such as the tilt angle and direction of their PV. It was also of interest for some users to be able to "compete" against the forecast by seeing if one was currently behind or ahead of the forecast. When rating the usefulness of the forecast as a function the result was 4.9 (median 5) out of 7 where 7 was very useful and 1 not very useful.

In order to better compare the cost of electricity from the heating system a curve of the temperature was sought after.

7.3 Batteri - Battery

The *batteri* (battery) page is intended as a page that gives the user information about the system status as well as providing information about ancillary services or other services that the battery is providing.

7.3.1 Sketching Ideas

In order to make the user feel that their battery is making a difference and is being used, even though it is idle most of the time, it is important to have a functionality that *evokes these emotions*. It was also important to create a sense of community to better communicate that it is a team effort - that we as a unit can help make the grid safer and more stable. From these user goals, sketches were created, excerpts can be seen in Figure 7.5. In order to highlight the actions that the battery takes when contributing to the grid, *insatser* (contributions) were introduced which can give the user more information about the sequence of events during a contribution, such as duration and amount of energy required. This was done through a timeline where the user could interact and get a playback of the chosen contribution.

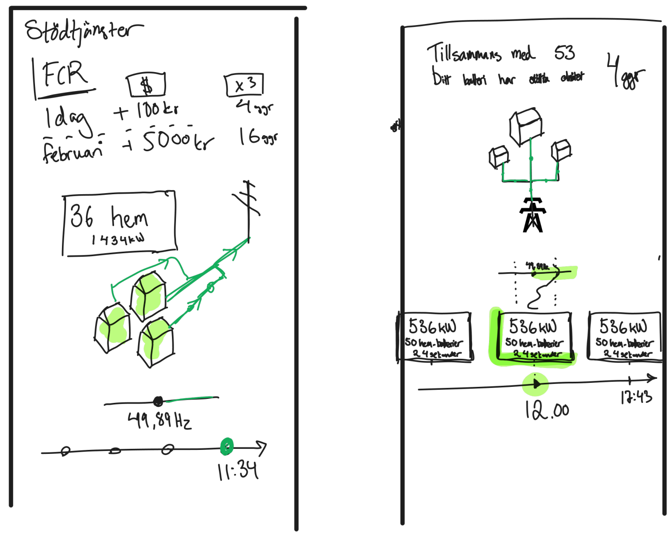

Figure 7.5: Battery sketch.

7.3.2 Interactive Hi-Fi Prototype

The interactive prototype of the battery page can be seen in Figure 7.6. Starting from the top, it consists of the same date picker that can be seen on most pages, keeping inner consistency. The next section is information about the battery as well as system status in order to fulfill user goals related to system status. The image of the battery is tappable in order to receive information such as cycle count, state of health and connectivity to the VPP. Below the information is a graph of the battery's state of charge. This is important to the user as the spikes in the graph represent FCR contributions. It also gives an indication of the amount of energy used in the contribution. As the energy required for each contribution generally is small it is of importance to communicate this to users so that they do not worry about the cost of electricity connected to a FCR contribution.

From the idea of playing back a sequence of a contribution, explored in the sketching phase, evolved the section *Din senaste insats* (Your latest contribution). This section lets the user see the latest contribution as well as all contributions from the chosen day. Once the play button in the square is tapped, the frequency deviation is shown to the right of it with the frequency curve animated. The frequency widget is designed with the blue field covering 49.9-50.1 Hz. The outer red field is the FCR contribution range. To indicate the direction of the flow eg. if the contribution was FCR-D up or FCR-D down, an animated orange flow appears from either the house icons to the grid icon or the other way around. For more information about ancillary servicves a button is added beneath which describes how they work.

To better convey the meaning of the community, collected information about the current state of the VPP Currently was added to the bottom of the page. Here users can see for example the total amount of homes connected to Currently as well as peak power.

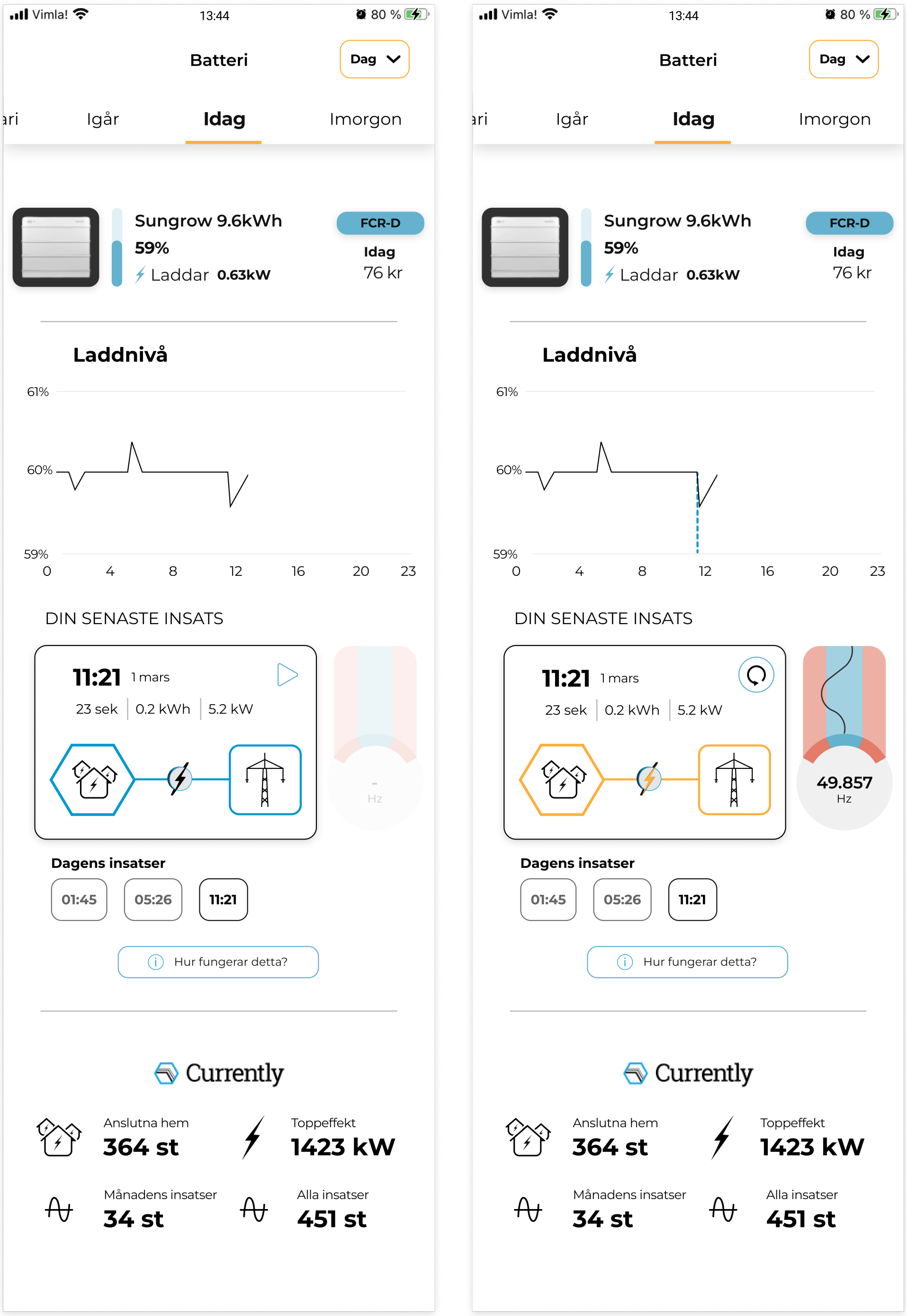

Figure 7.6: Battery prototype page. Bottom navigation has been hidden to show the full page

7.3.3 Learnings from Testing

The battery page caused some initial confusion among participants in the supervised testing. The main reason is that not all respondents were familiar with ancillary services (such as FCR-D in the prototype scenario). However, after getting to know the page for circa a minute, the users found the interface less confusing.

Several users expressed that they liked the visualization of what contribution the battery had made in the past. The unsupervised testing gave the feature a usefulness rating of 5,56 (median 6) out of 7. The battery information together with the summary of all devices in the VPP made one of the users express: "I'm one of the good guys helping the grid, and I'm getting paid for it". This is in line with the theory that battery storage and VPPs are beneficial for transitioning to a grid with more RES section 2.9. One user expressed "I want to see that my investment is used". This satisfied with the visualization and caters to user goal 12 *Ability to see battery activity with regards to ancillary services and Currently.*

There were some misinterpretations of the content. One user interpreted "23 sek" as 23 Swedish crowns while the meaning of "23 sek" is 23 seconds. Another issue was the order of information on the page caused some confusion among users. Not all users could make the connection between a contribution in FCR-D and the resulting spike in the SoC graph.

Some users wanted slightly more information about the battery and its performance. Each system is tested for power delivery. Showing the test result would increase visibility of system status.

It was also requested to provide a number for income divided by power (kr/kw). The income for the ancillary service changes every day based on the bidding process.

Users also requested to see the wear that ancillary services have caused their battery. This is beneficial since ancillary services in general are more lenient for the battery compared to full cycles when saving solar energy (the default application of a home battery). A full cycle of a battery causes more wear than using the equivalent energy while keeping within 30-80% SoC. The explicit request was to show how many full cycles the energy used in ancillary services corresponded to, even if this comparison is a bit flawed. This comparison is however flawed in the way that it will show more wear to the battery than actually caused, making the cycles count a "safe" prediction.

There were also requests about comparing ancillary services to EA, PS and saving solar. The comparison would show the potential income for each task for the battery, making the decision on task transparent for the user. This is in line with the company's communication guidelines. The user however does not have to choose what task the battery should perform each day. At the present time, this is handled automatically by the system. This comparison comes with some problems and they are further discussed in section 10.6.

Users wanted better visualization of the energy flow in the battery. This is beneficial for the company since energy usage in ancillary services is a concern for users. The energy used is typically small in quantity and does not cause a significant cost for the owner. This feature might not be of interest for all types of users. However, the current users are early adopters and generally appreciate extensive information. They are technically skilled and like to be able to see the full picture of the system, managing to sort out information that they are interested in.

7.4 Ekonomi - Economy

The purpose of the *ekonomi* (economy) page is to facilitate graphs and calculations that users were often missing from other energy related apps as well as to assist in creating better understanding of the value of their facility.

7.4.1 Sketching Ideas

Ancillary services is a unique selling point for the company as it creates a significant revenue stream for the customers. When sketching for the economy page focus was put on showcasing the profitability of ancillary services as well as to show the value of PV production. Often, when a solar installation company offers to install solar panels and batteries, they include a specification of yearly revenue and the break even point in their proposal. Similar calculations were also found in Facebook groups and it was deemed an area of interest for many customers. Therefore sketches were created around how these calculations could be visualized which can be seen in Figure 7.7.

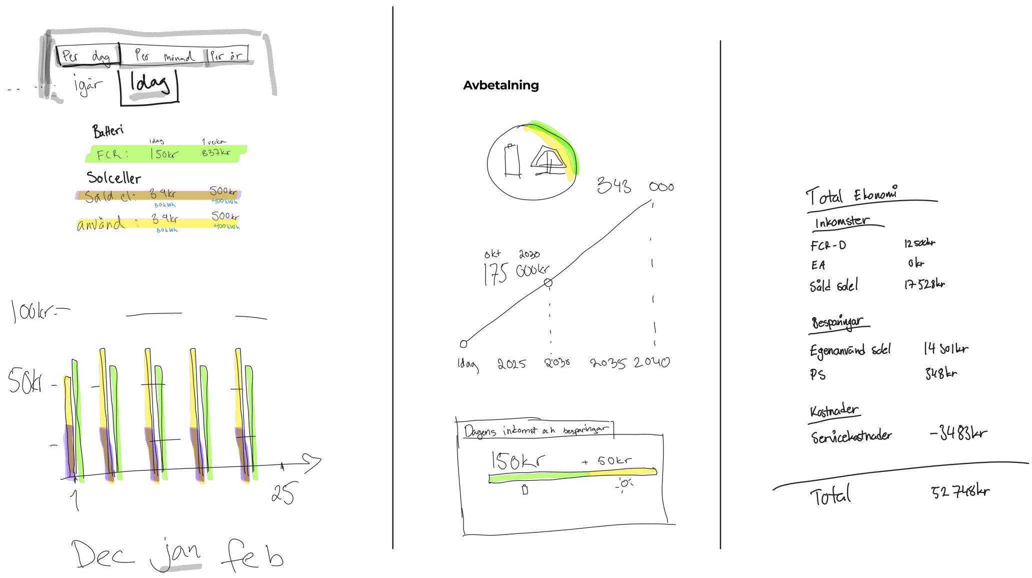

Figure 7.7: Economy sketching ideas

7.4.2 Interactive Hi-Fi Prototype

On this page (Figure 7.9) the user is first met with a graph of the monthly income from ancillary services as well as from sold electricity. As the user taps a vertical bar in the graph, that day becomes highlighted, as can be seen in Figure 7.8, and the average monthly income is shown as a horizontal line in the graph. This page is important for the company as it gives a summary over the income of ancillary services in comparison to the remaining income and expenses and further highlights the economic incentive of being part of the VPP. For more information on how the numbers are calculated, an information button was added below every graph on this page, leading to an overlay explaining the calculation. The buttons adhere to the usability principle of help and documentation.

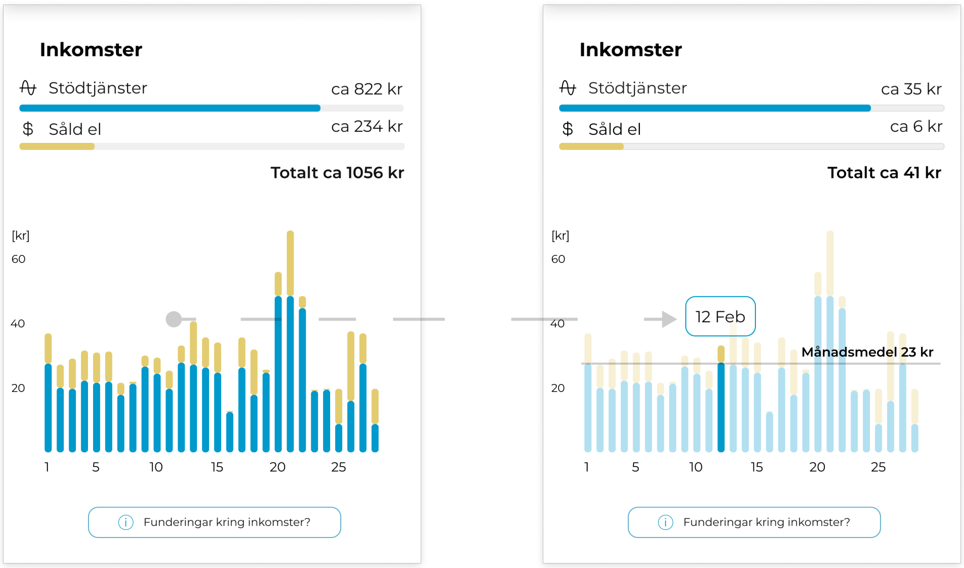

Figure 7.8: Income graph. As the user taps a vertical bar in the graph, that day becomes highlighted as is shown in the right image.

The second graph on the page shows the monthly electricity costs being compared to the previous month. The widget below the graph is a line graph that shows the deviation of electricity costs per day compared to previous month. The previous month is set as a straight line and the current month is then compared to that value. The possibility to change the date that is being compared can be done by tapping the pen icon.

The section *Ekonomisk sammanställning* (economic summary) presents a summary of the chosen month. Here the total usage is stated which includes both bought electricity as well as self-consumed electricity. As the self-consumed electricity is a saving and not an actual cost, it was separated from the rest of the numbers and colored in a blue shade used for self-consumption in all graphs within the prototype. Below the summary is a comparison to the previous month in percentage and in text. Last, the widget for *Återbetalningstid* (Repayment period) is placed. It first gives the user a calculation of the total income generated from ancillary services and sold electricity and then further divides these numbers in different *delmål* (milestones) such as "Installation" and "Inverter". This is visualized through horizontal bar charts that get filled as revenue is gained over time. It also gives an estimate of when the facility will be paid off by extrapolating the historic income.

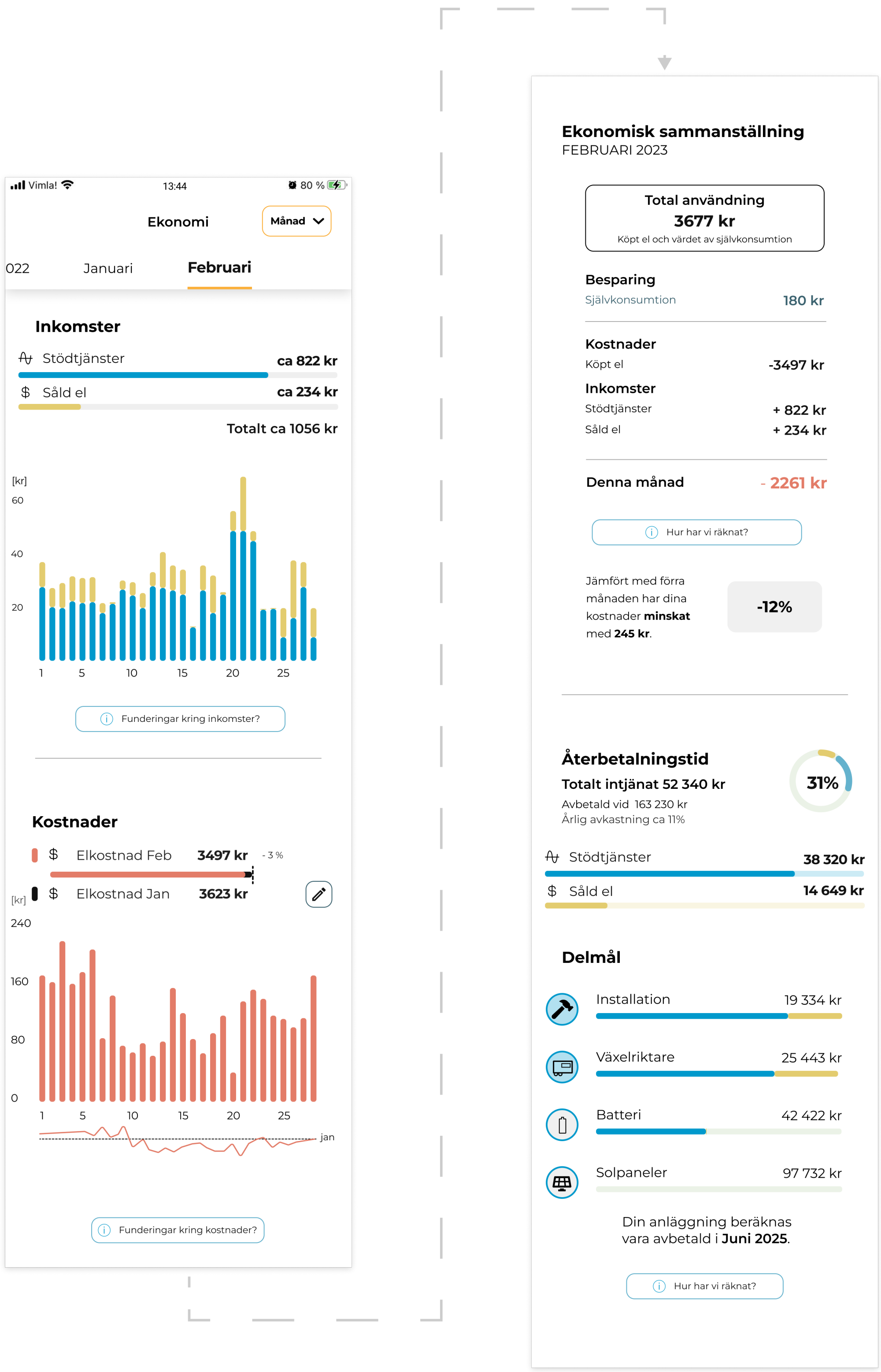

Figure 7.9: Battery prototype page. Bottom navigation has been hidden to see full page

7.4.3 Learnings from Testing

The first graph showing the income was simple to grasp for most users in the supervised user test. The task of tapping a certain day to get more information about that day was solved by 86% with an average time of 30 seconds (median 14 seconds). As the date picker was not fully functioning this could have had an impact on the result, as it could be natural for a user to assume that this would be one way of finding individual dates.

In the second graph on the page the users had a difficult time understanding the trend curve located below the graph. It wasn't until after the user clicked a certain day that the concept of comparing became a little bit clearer. Even after entering into the day view, it was still unclear for some users. Even though most users appreciated the ability to compare, most deemed it unnecessary to compare to something other than the same day/week/month last year. Although this is a fair point, the user won't be able to compare the energy costs unless they've been using the service for a year. Once the concept of the trend curve was further explained in the supervised tests, it was an appreciated feature.

The economic monthly summary uses self consumption as means to communicate the value of consumed energy from solar or battery. The results from the unsupervised test showed that 14/16 users understood that the self consumed electricity was not actual money that the user will get paid but rather a value to describe what they've saved by using the produced electricity.

The final graph showing the repayment period was given diverging ratings in the testing. Some stated that it is a great function while others said it was not really that necessary. All in all it seemed to be a nice widget to have and from the unsupervised test it got a mean of 5.4/7 (median 6) on a scale of not so useful (1) to very useful (7). An idea was to include the installation date of the facility. It was also necessary to make it clearer what goal the user is currently fulfilling and which goals had already been completed. Another functionality that could be included is adding monthly costs that are related to the facility to get a better calculation of the actual repayment period. As these are calculations that some users do in a spreadsheet it's of importance to find a balance of functionality so that it suits most users.

Another idea from the supervised user test was to further visualize the monthly economic summary so that it was possible to see the net of costs and income per day. This would allow the user to each day see if the facility generated enough value to cover the expenses or not. This could further be incorporated in the overview page as it is a value that would change throughout the day.

7.5 Navigation

This section presents the results of developing the navigation for the prototype.

7.5.1 Sketching Ideas

Keeping navigation simple is an essential part of an app's design. It was decided that a flat navigation with scrollable pages would be the best design for the prototype, as mainly having top level hierarchy with lateral navigation reduces navigational excise and confusion. The navigation through the prototype is done with the bottom navigation bar that is always present as can be seen in Figure 7.10. The pages that require switching of dates to navigate back and forward in time were provided with a tab navigation. The tab navigation lets the user horizontally scroll through a list of either dates, months or years depending on what is chosen with the date picker on the top of the screen. Both these features are in line with the guidelines from Material Design 3 subsection 3.4.5, as well as keeping outer consistency with other similar apps.

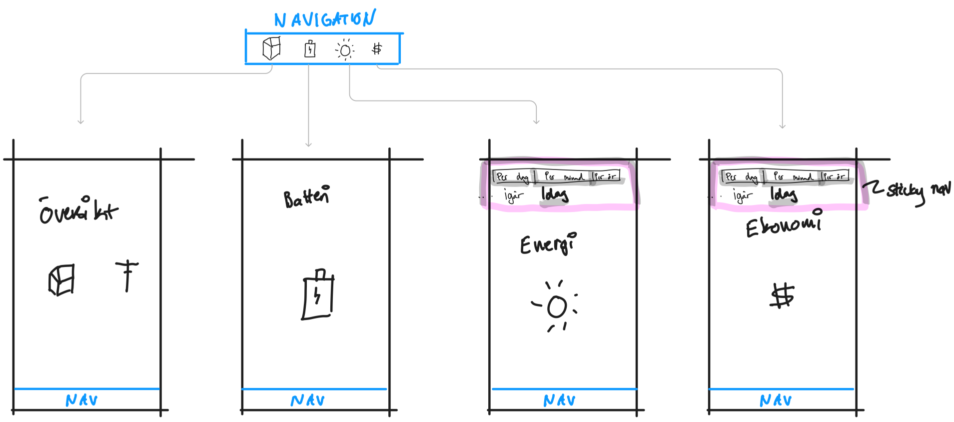

Figure 7.10: Sketch of navigation in the prototype.

7.5.2 Interactive Hi-Fi Prototype

A flat design navigation was chosen in the interactive prototype. The general idea is to have one scrollable page for each part (overview, energy flow, battery etc.) of the prototype, that can be reached by the bottom navigation as can be seen in Figure 7.11. The page "Profile" is present in the navigation but does not have its own section in this report. It is a page that contains settings such as name, address, notifications and similar. The page is a placeholder in the prototype and contains no interaction. It has not been given extensive attention since settings will differ depending on implementation. A bottom navigation bar was chosen over other menu options as the number of destinations are limited to five, thus adhering to the Material Design guidelines. Some features of the prototype were however decided to be reached with forward navigation. One such example is the settings for the repayment period feature, where the user inputs the cost of his/her solar and battery system as can be seen in Figure 7.12. The argument for this decision is that putting it in conjunction with the graph would make the page scroll long and cluttered. The settings could be be done with a modal instead, but as the navigation is flat to start with an additional level can be manageable without complicating navigation. Further, explanatory texts are placed in overlays in several places of the prototype. Several of the concepts within the system are complicated and might need further explanation. The overlays provide some information about how specific features are working, such as what data goes into the prognosis or what parameters are used to calculate the cost of electricity.

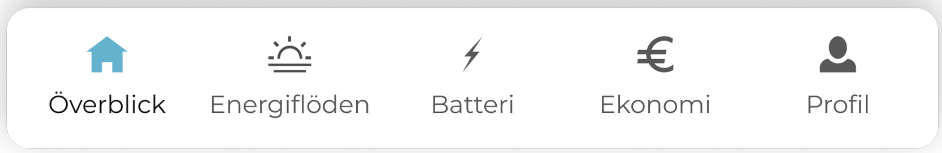

Figure 7.11: Bottom navigation in the interactive prototype.

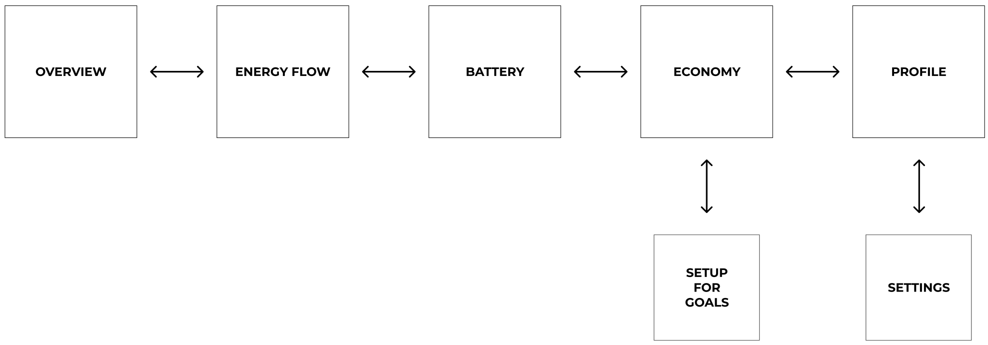

Figure 7.12: Information architecture in the interactive prototype.

7.5.3 Learnings from Testing

The navigation of the prototype proved to be effective in fulfilling user goals and potentially in an efficient way. Most users had no trouble navigating to the corresponding page and finding the graph or feature requested in the test. The flat navigation design of the prototype was deemed easy for the users to understand.

In the unsupervised testing, respondents solved the assigned task on average in 25 seconds (median 14 seconds). The maximum and minimum outliers are 1 min 34 seconds and 3 seconds. As these numbers have no baseline attached to them, it is hard to judge whether these numbers should be deemed as positive or negative. However, they can serve as a baseline for future iterations of design.

The first interactive task contained navigation and interaction that was useful for completing the two following tasks. The first task was completed on average in 25 seconds (median 28) while task two was completed in 19 seconds (median 14). Task three showed an increase in average time spent, 30 seconds (14 median). One explanation is that task three required navigating to a new page and finding the interaction on that page. However, the design keeps inner consistency and it is deemed that efficiency will increase with more usage. All tasks are presented in Appendix section B.3 and the full results in Appendix B.4.

Some background knowledge about energy systems are needed to fully comprehend the prototype. Some knowledge is provided in the informative overlays, but as these are brief in their explanation, they do not provide all knowledge that a user might need to fully comprehend the information. A discussion on what information to include is provided in section 10.9.

7.6 General Learnings from Testing

The general feedback from testing was positive and most users were able to understand the content presented. The result from the semantic word scale answered after the supervised user test can be found in Appendix B.2. The prototype's appearance was found to be perceived as gender-neutral and with clear communication. The information presented was thought to be sufficient and not overwhelming. The content of the prototype was found to be easy to understand by most participants.

8

Final Design

This chapter presents the final design of the prototype. Each page within the prototype and the features present are described together with how they fulfill their **main** user goal. The chapter ends with a complete list of how each user goal is fulfilled by several features.

8.1 Overview

The overview page Figure 8.1 is intended to provide a full system overview without detailed information. It is designed to have quick access to all parts of the system together with brief data.

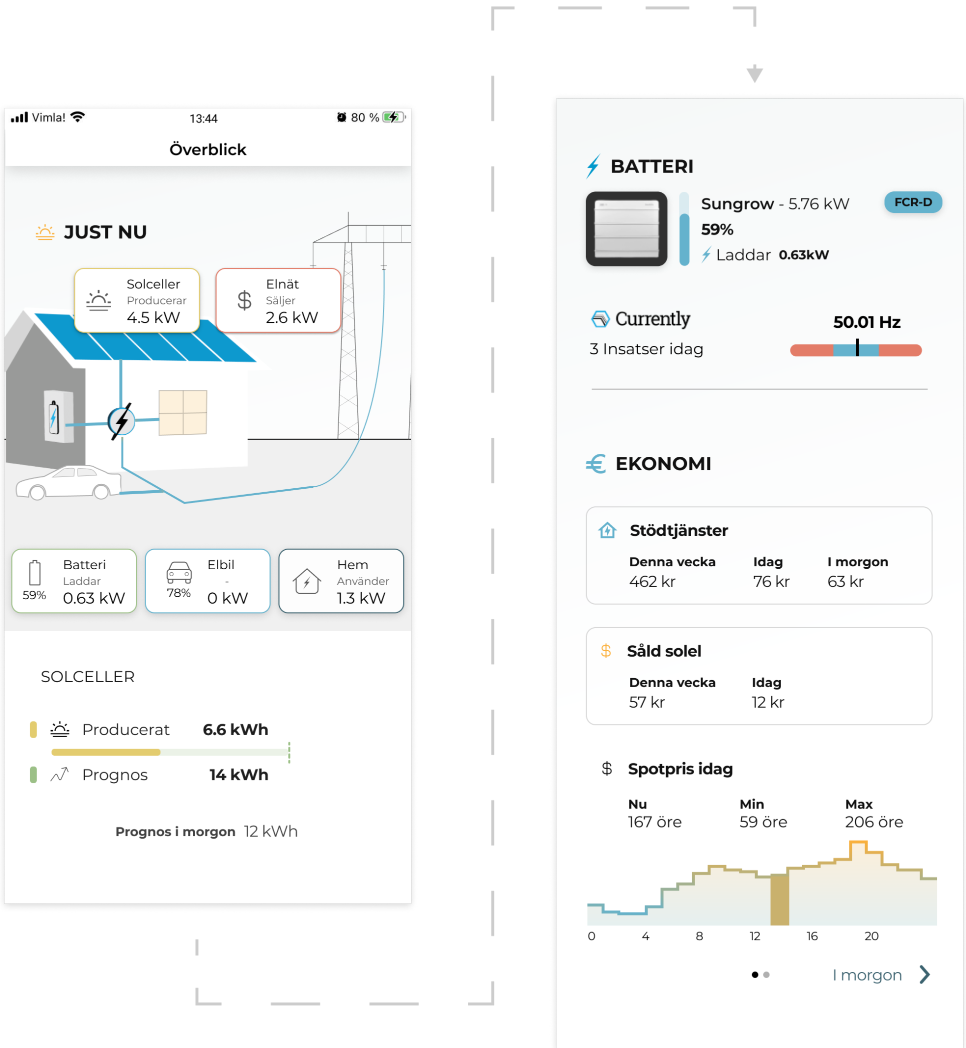

Figure 8.1: Overview page

8.1.0.1 Right Now

The element *Just nu* (Right now) Figure 8.2 is designed to fulfill several user goals. Primarily, it provides a quick overview of what the system status is, fulfilling user goal 1 *Ability to quickly access current flow of energy eg. current production and consumption*. The animation (not present in the report) visualizes the direction of the energy flow. The momentary power usage/production for each entity is displayed on each card.

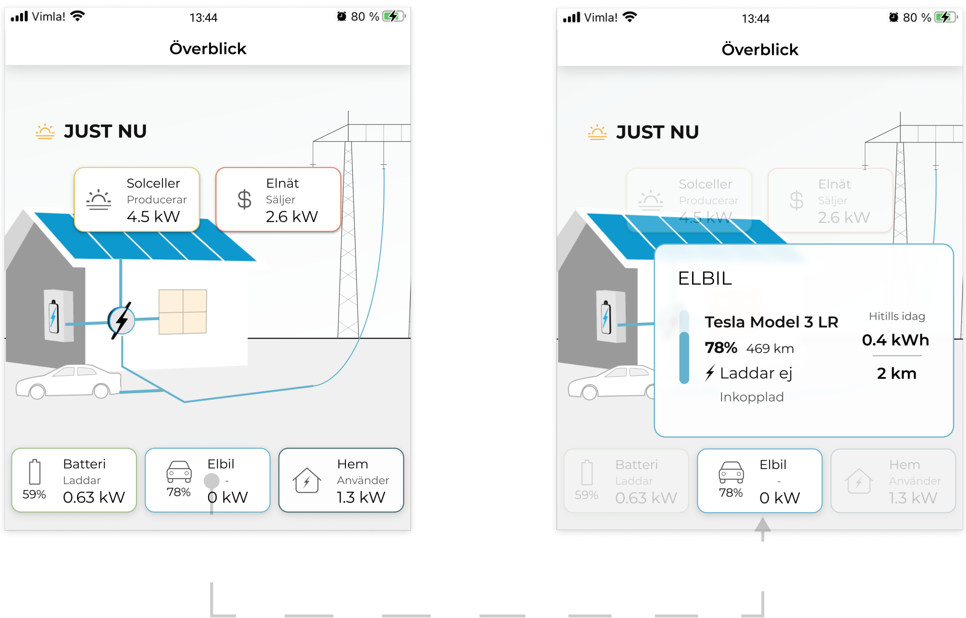

Figure 8.2: Right now element on overview page. To the right, the car card has been clicked.

8.1.0.2 Solar Panels

The *Solceller* (Solar panels) card on the overview page Figure 8.3 provides the user information about today's production and forecast of production for today and tomorrow. This enables the user to make conscious decisions about how to consume their solar electricity, catering to user goal 18 *Ability to see facility in regards to sustainability*. An example would be if the user has the goal of charging their EV primarily with solar electricity.

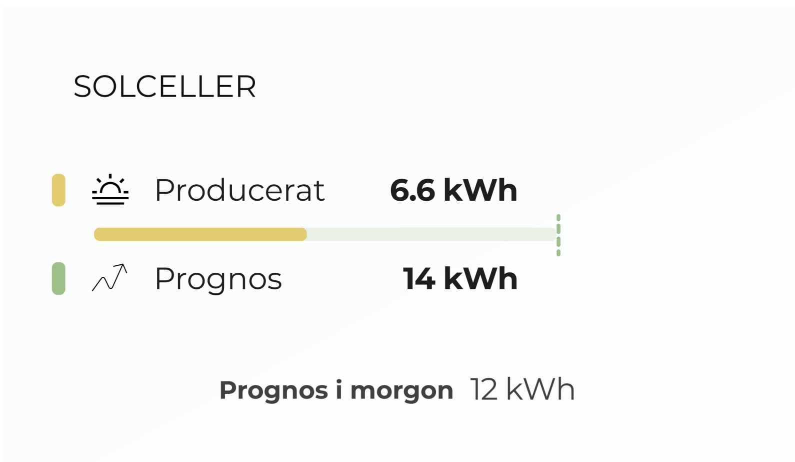

Figure 8.3: Solar panel card on overview page

8.1.0.3 Battery

The *batteri* (battery) card Figure 8.4 on the overview page provides the user information about the current status of their battery. Current ancillary task, SoC, power usage and the number of contributions for today is displayed. This adheres to user goal 10 *Ability to see status of battery eg. state of charge* and user user goal 11 *Ability to see battery service setting eg. type of ancillary service.*

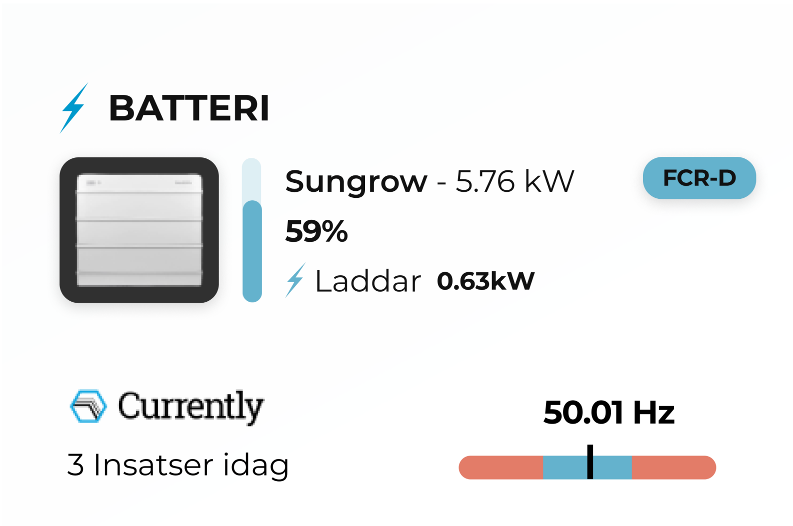

Figure 8.4: Battery card on overview page

8.1.0.4 Economy

The *ekonomi* (economy) card Figure 8.5 on the overview page provides the user with information about the economy for today, tomorrow and the current week. The information had been split into two sections, one for *Stödtjänster* (ancillary services) and one for *Såld solel* (sold solar energy). The income for both these categories are displayed cumulative over the week and for today. As the ancillary services are traded day ahead, tomorrow's income is also displayed. This caters to user goal 14 *Ability to see income generated by facility and from ancillary services.*

Figure 8.5: Economy card on overview page

8.1.0.5 Spot Price

The card *spotpris idag* (spot price today) Figure 8.6 provides the user information about the current electricity price when buying from the grid. This information is also relevant for selling electricity, as people usually get paid the spot price (with some additional payment) when selling electricity. This caters for user goal 9 *Ability to plan for optimal time to consume electricity.*

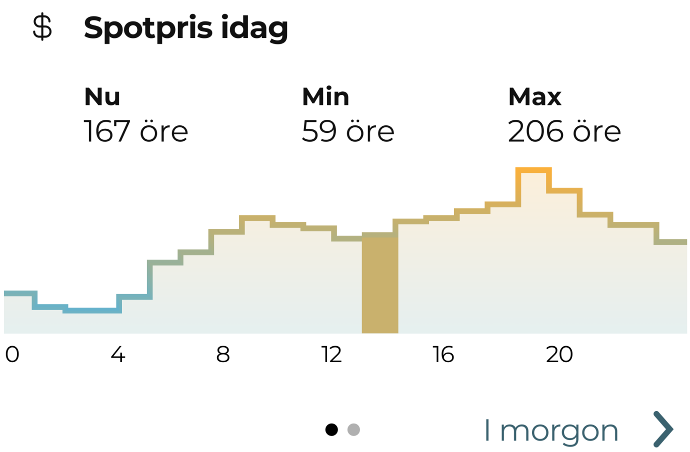

Figure 8.6: Spot price card on overview page

8.2 Energy Flow

User goal 7, *Ability to see energy consumed and cost of usage* is fulfilled by the energy flow page, Figure 8.7. The graphs related to the energy flow were all placed on a scrolling page, instead of separating them. This allows for placing the curve of the solar production as a common denominator in all graphs. This was a way of telling a story about the consumption and production, by always being able to compare to solar production.

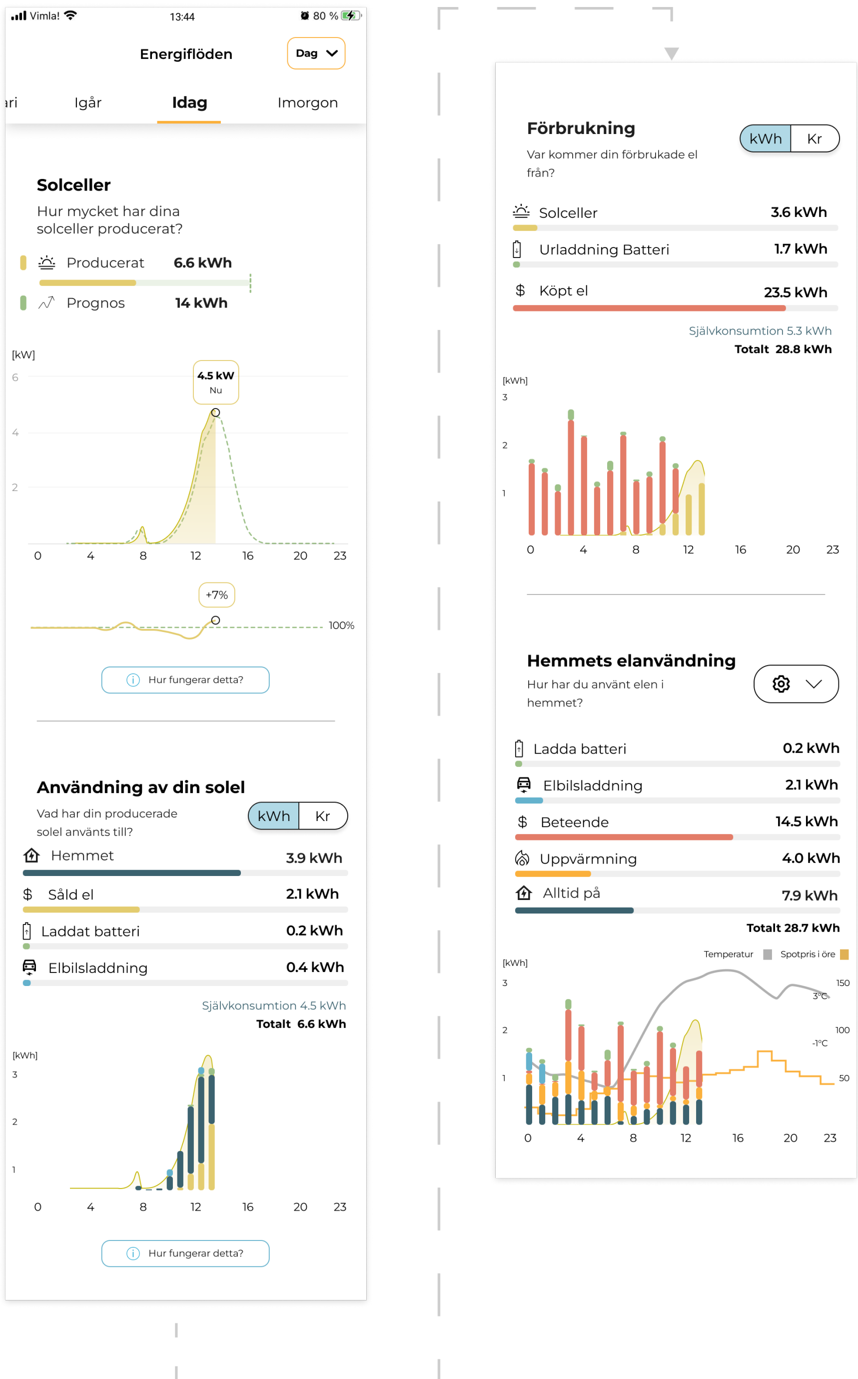

Figure 8.7: Energy flow page

8.2.1 Solar Panels

The page starts with solar production compared to the forecast. It is introduced with a bar showing produced electricity in yellow over a green background. The green background represents the forecast and the full width represents the forecast amount of electricity. Having the forecast allows users to make conscious decisions about when to consume their solar electricity, catering to user goal 18 *Ability to make decisions based on the most sustainable outcome.* A widget showing the deviation in percentage from the forecast was placed beneath the graph which allows the user to see how well the system has been performing throughout the day in comparison to the forecast. This caters to the user goal 5, *Ability to indicate whether solar panels are functioning properly or not.* By tapping and scrubbing on the graph the user will get information from different timestamps from the chosen day as can be seen in Figure 8.8.

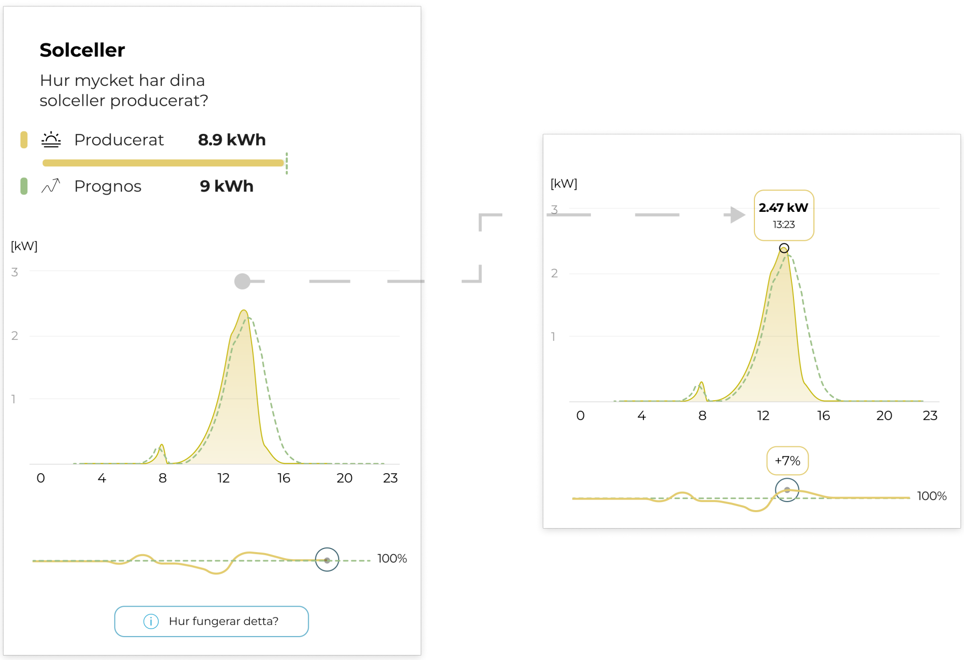

Figure 8.8: PV production with prognosis

8.2.2 Usage of Solar Electricity

This graph shows what the produced solar electricity has been used for, catering mainly to user goal 8, *Ability to see solar energy consumed.* The amount of electricity divided into different components is represented by four horizontal bars, where each bar signifies the usage of produced solar electricity. The width of each bar corresponds to the respective amount contributed by each component. The graph also gives the user the possibility to see the value of solar electricity of the selected day by tapping the button kWh / Kr as can be seen in Figure 8.9. The calculation of money is done with the spot price and includes all fees and taxes making it accurate for most users. For users with fixed tariffs, this can be defined on the profile page. The section caters to user goal 6 *Ability to see economy related to solar panels* and is also a way of matching between the system and the real world as it uses concepts more familiar to the user.

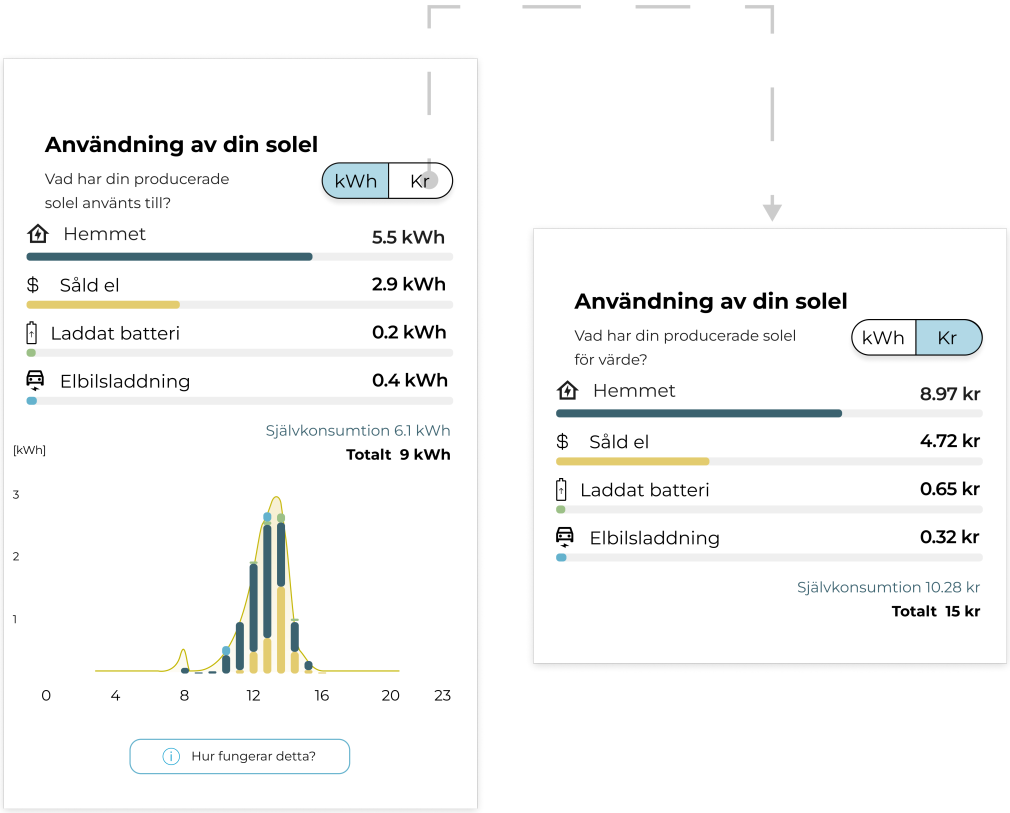

Figure 8.9: Energy flow page

8.2.3 Electricity Usage

This graph shows the sources of the used electricity, catering for user goal 3, *Ability to see historic production and consumption* and also 4, *Ability to see level of self consumption*. By tapping and/or scrubbing the graph the user can go in to a specific time span as can be seen in Figure 8.10.

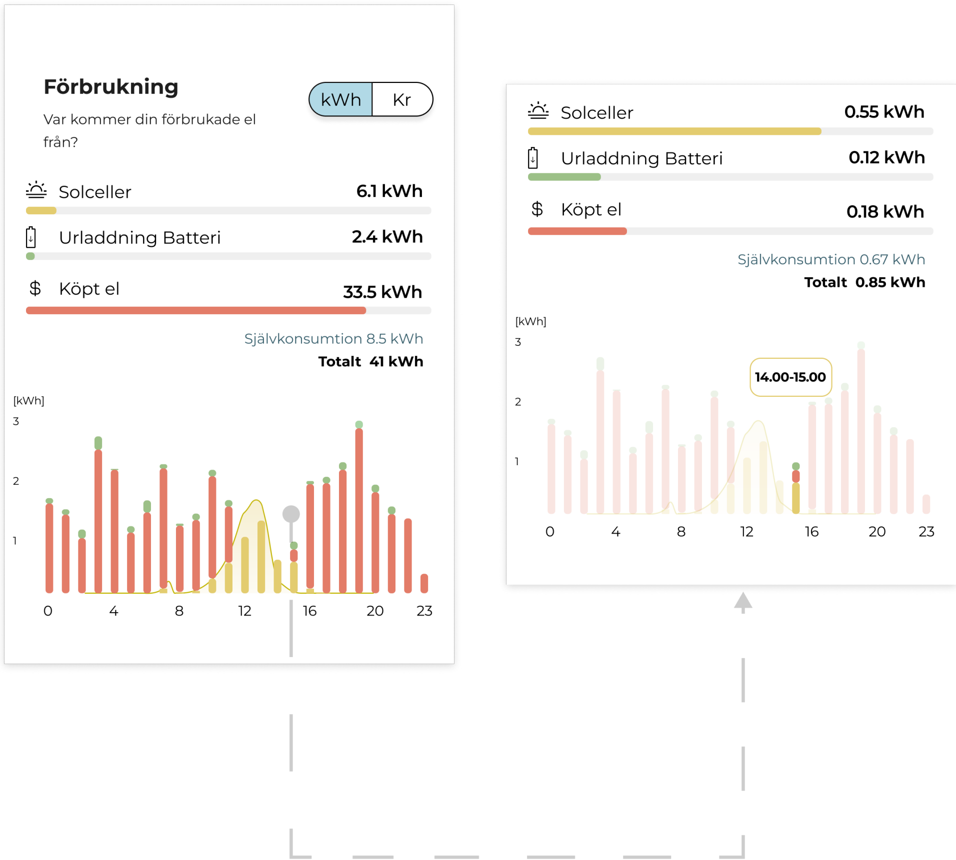

Figure 8.10: Energy flow page

8.2.4 Home Usage

The graph *Hemmets elanvändning* (Home usage) (Figure 8.11) goes into finer details and shows what the electricity was actually used for and is divided into Charging battery, EV-charging, Behavior-related, Heating and Always on. *Behavior-related* means usage of electricity from things such as lights and cooking where *Always on* means things such as the refrigerator. The graph also allows the user to include the curve for the spot price as well as the outdoor temperature. This graph is meant to be a visualization where users can modify to meet their respective needs. This graph also makes it easier to plan future consumption based on temperature, spot price and solar production catering for user goal 18, *Ability to make decisions based on the most sustainable outcome.*

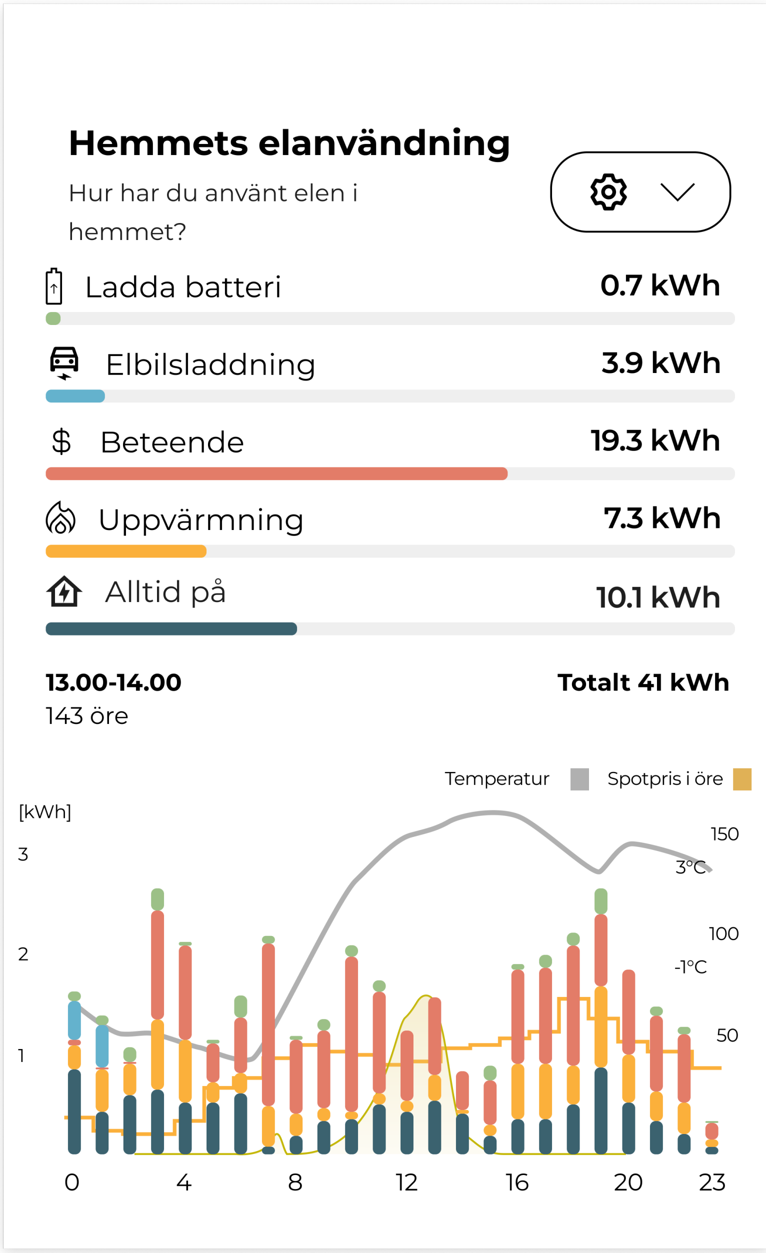

Figure 8.11: Energy flow page

8.3 Battery

The battery page (Figure 8.12) contains information about the battery status and the contributions it has made in the past. It also contains information about the VPP. An overlay can be accessed with technical statistics of the battery.

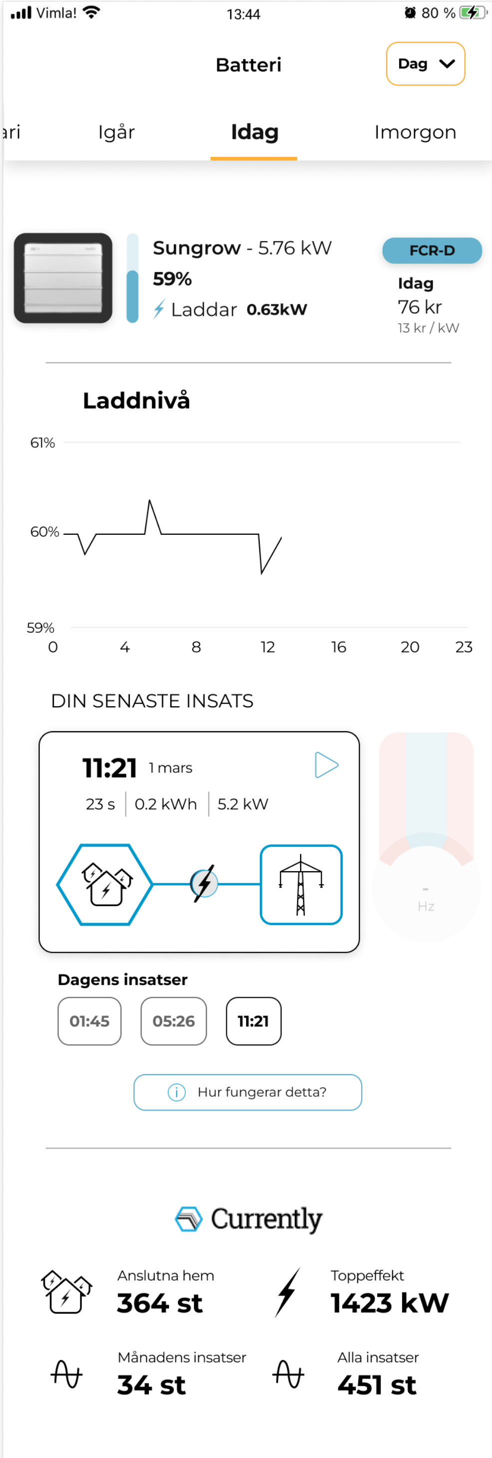

Figure 8.12: Battery page

8.3.1 Battery Status Overlay

The overlay that can be seen in Figure 8.13 appears when the battery is tapped and shows the battery status and technical statistics. It also contains connectivity status between the computer (CM10) that controls the system and it's connections to the internet, EIB, inverter, battery and smart meter.

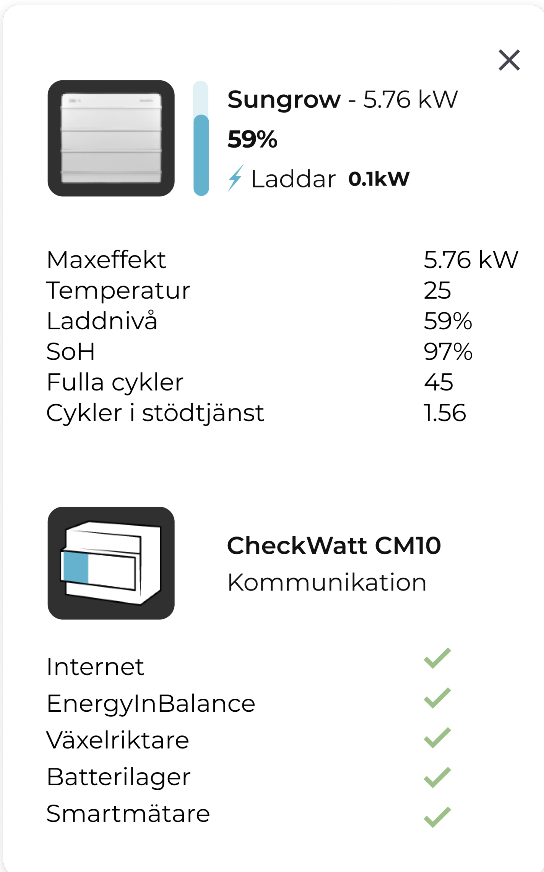

Figure 8.13: Battery page

8.3.2 Contribution Overview

The contribution overview (Figure 8.14) provides the user with several types of information about the battery and its status. The first part of the view shows the same information as displayed on the battery card on the overview page.

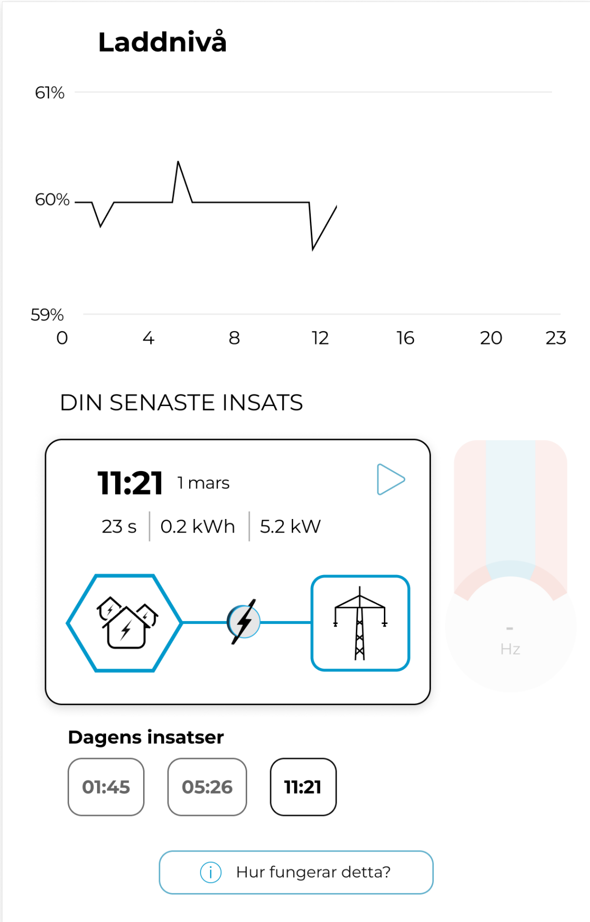

Figure 8.14: Contribution overview on the battery page

The *laddnivå* (state of charge) graph shows the user how the SoC has been on the chosen day. Further down the page, *din senaste insats* (your latest contribution) is displayed. This is an interactive card (Figure 8.15) where the user can replay the latest contribution the system has made to the grid. The animation provides information about the energy flow and the frequency of the power grid. This animation can be of help for users explaining ancillary services to others not familiar with the concept. As this is a novel concept this animation works as a means of communicating ancillary services in an entertaining fashion. Further down the page at *dagens insatser* (contributions today) the user can see other previous contributions and choose to replay them as well. This functionality caters to user goal 12, *Ability to see battery activity with regards to ancillary services and Currently* and user goal 13, *Ability to see that the battery is performing work.*

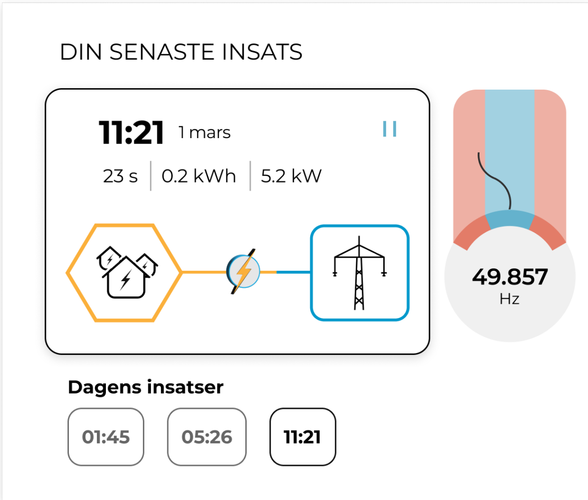

Figure 8.15: Replay of contribution

8.3.3 Overview of the VPP Currently

The overview of Currently (Figure 8.16) provides information about the performance of the VPP. Number of connected homes, peak power, contributions this month and over all time is presented. The intention of this information is to get the user to feel that they are part of something bigger. Together with other connected homeowners, they are contributing to an energy system that can facilitate an increasing amount of renewable energy sources. This adheres to user goal 17, *Ability to see facility in regards to sustainability* provided that the user knows how a VPP is beneficial for the power grid. This is discussed in section 10.9.

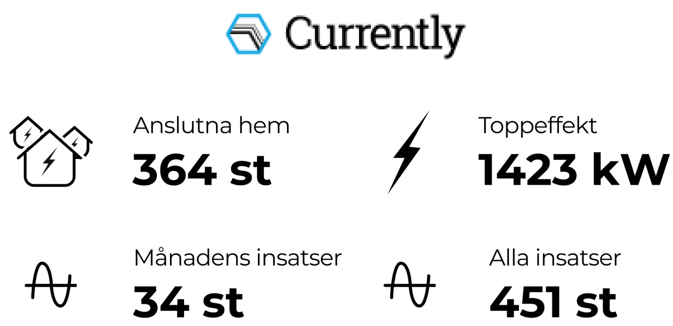

Figure 8.16: Statistics of energy resources connected to the VPP Currently

8.4 Economy

The economy page (Figure 8.17) is intended to show the economy of the system. There are several graphs and summaries on the page showing information from different perspectives.

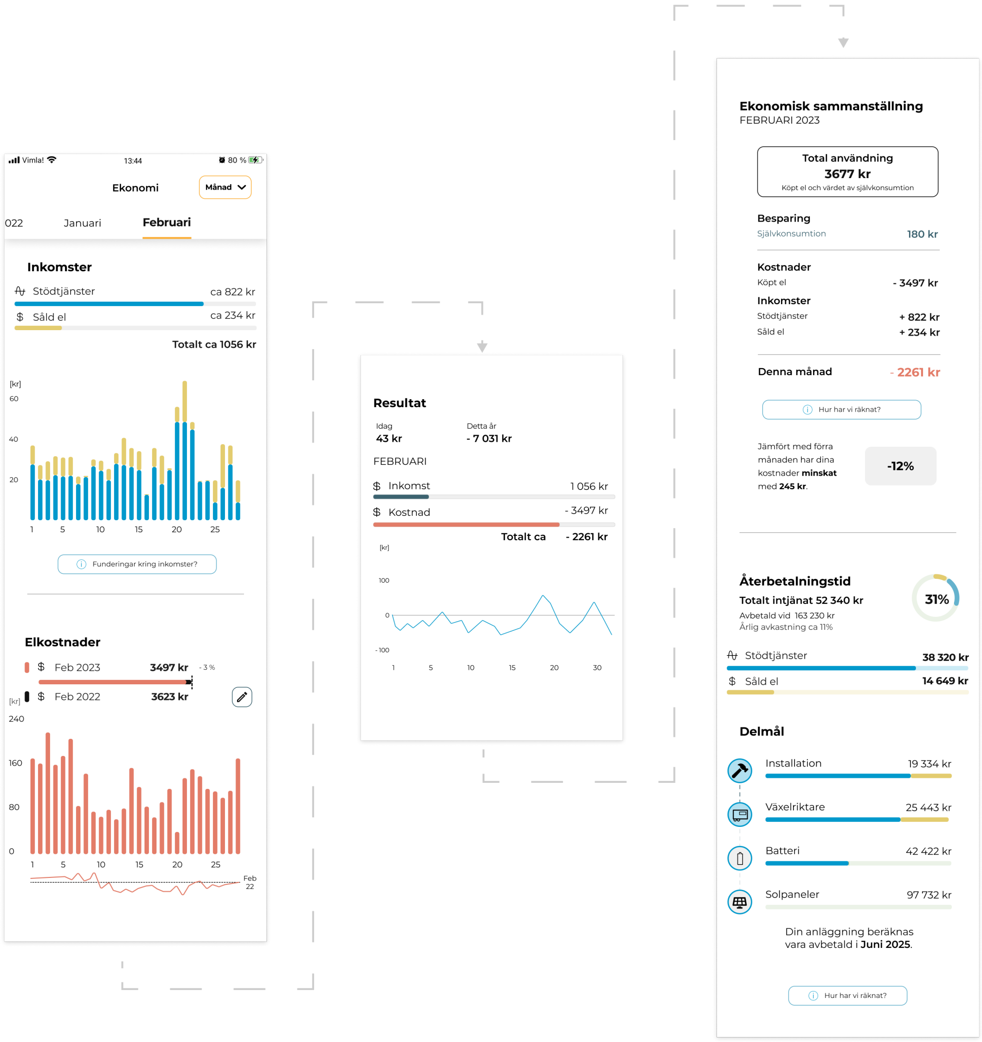

Figure 8.17: Economy page

8.4.1 Income

The income section Figure 8.18 shows the user how their system has earned money. It is categorized into revenue for ancillary services and sold electricity. This section fulfills user goal 14, *Ability to see income generated by facility and from ancillary services.*

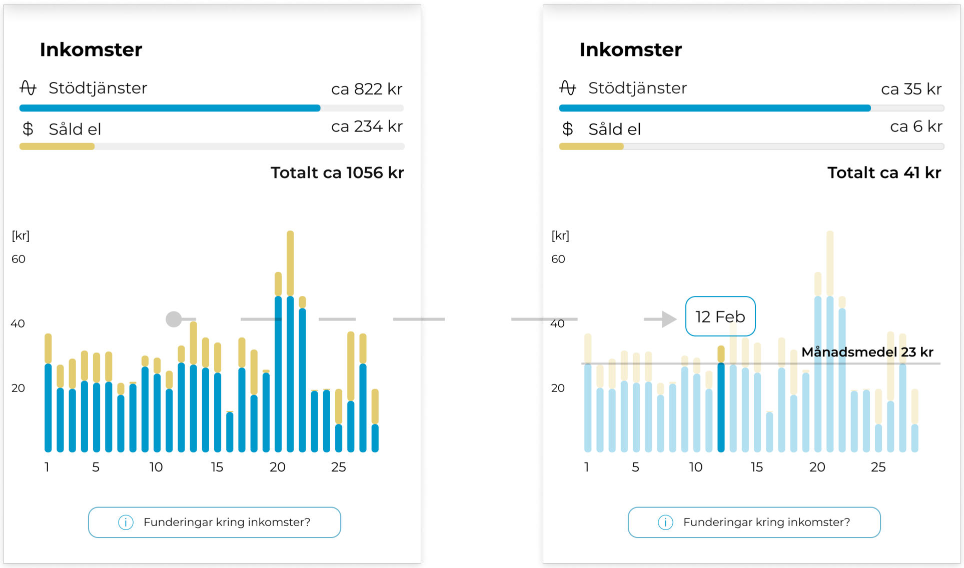

Figure 8.18: Income generated by the system

8.4.2 Electricity Costs

The graph *elkostnader* (electricity costs) Figure 8.19 shows the costs of electricity usage. The graph shows a comparison to a previous month. The default is the same month as the current one, but a year ago. This provides information that could be useful if the user is trying to reduce their electricity consumption/cost. It is possible to change the month for comparison if needed. The dashed line indicates the comparison month as a baseline and the red line shows the trend of the current month. The information in itself does not have a single user goal, but works towards the user goal stated in the next section.

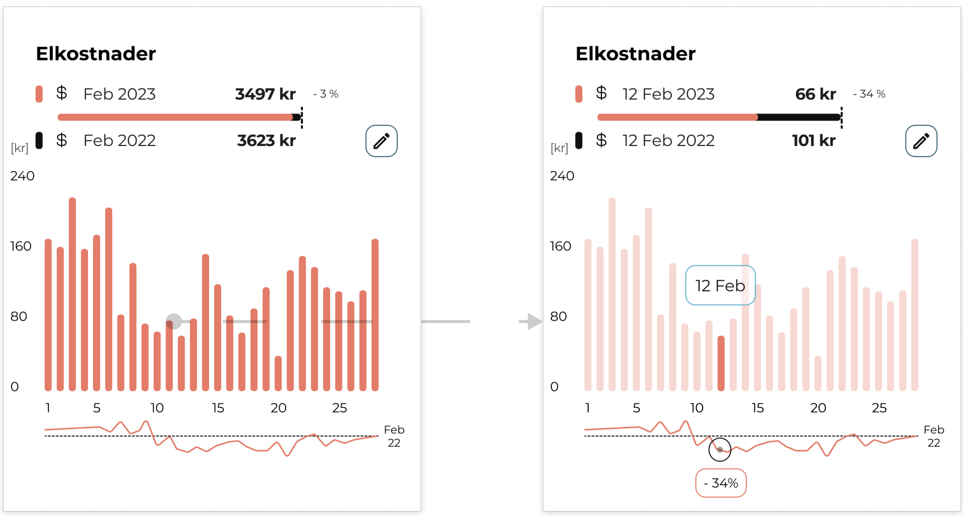

Figure 8.19: Costs for used electricity

8.4.3 Results

The *resultat* (results) Figure 8.20 section summarizes the income and expenses over time. There is a gray horizontal line which indicates zero. The blue line shows each day's results over a month, while the horizontal bar graph above shows the result of the month. This section will be interesting to follow over a year. The daily income will climb approaching the summer months with the highest solar electricity production. It will then decline in the autumn. There is a potential for a user to see this as a competition over the year. The user could feel that he/she has "won" if the system generates more income than the cost of electricity usage, over a year. This section caters to user goal 15, *Ability to see a summary of costs and income.*

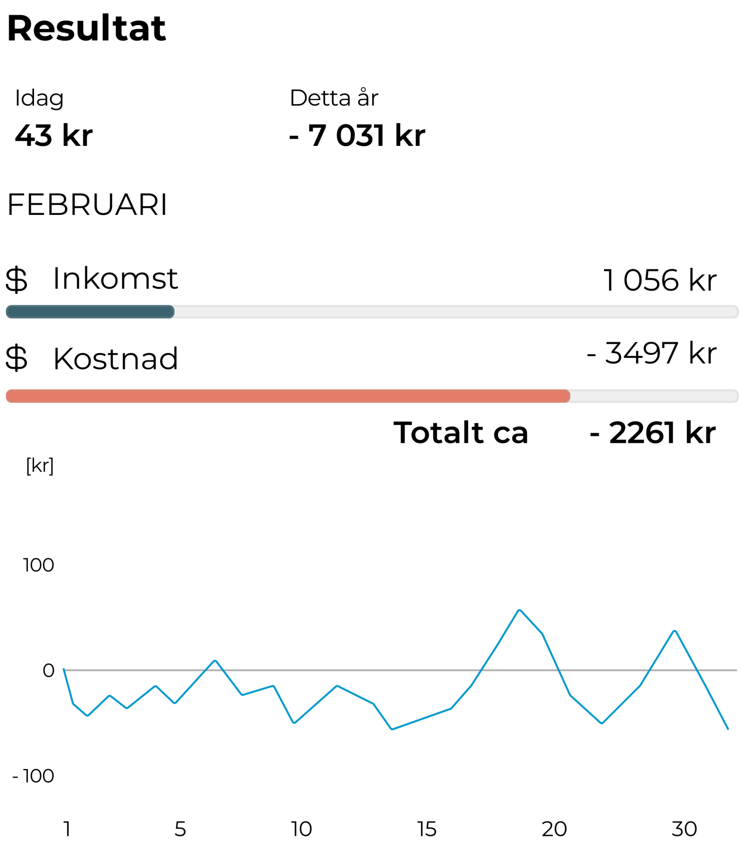

Figure 8.20: Results of income and costs

8.4.4 Economic Summary

The section *ekonomisk sammanställning* (economic summary) in Figure 8.21 contains information that is similar to the Results graph in the section above. However, there are some differences. While the above section only shows income and costs, the summary also provides a value for self-consumption of solar electricity. This is a value that is often overlooked. Even if self consumption does not pose an income/cost for the user, it has a value. The value presented is a calculation of what it would have cost to buy the electricity from the grid. The total value (bought and self consumed) of electricity consumption is displayed at the top. Further, the summary provides details about what values are going into the calculation. The bottom line is the economic result of the month. Finally, a percentage of increase/decrease in the economic result is displayed. The summary is inspired by a balance sheet and keeps a similar format. This section fulfills user goal 15, *Ability to see a summary of costs and income.*

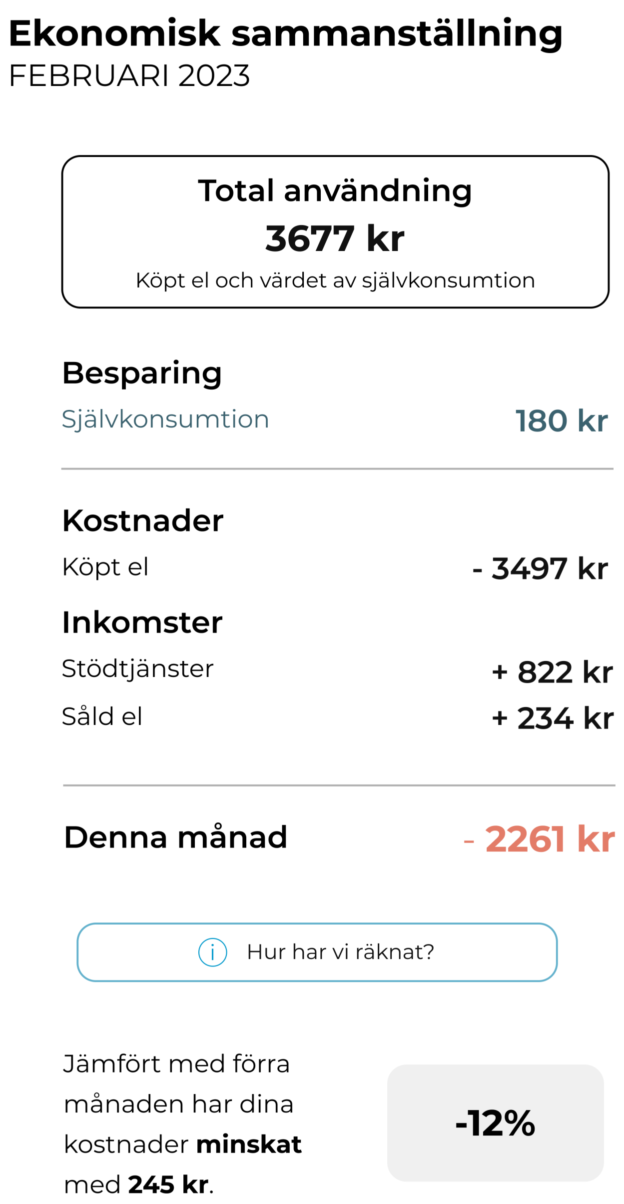

Figure 8.21: Economic summary of the month

8.4.5 Repayment Period

The section *återbetalningstid* (repayment period) Figure 8.22 is intended to help the user analyze their return on investment. The top part contains information about progress towards break-even, total income, total cost, yearly return and what functions have generated income. The section *delmål* (milestones) is intended to make the user feel there is progress towards break even. The user can input their cost for each part of their solar/battery installation and order them in a way that they think is suitable. The top item, installation, is first filled and then subsequently the following ones. Finally, the income is extrapolated and an estimate of when break even is achieved, is displayed. The repayment period section fulfills user goal 16, *Ability to see a forecast of return on investment*. As installers of solar panels often provide a forecast of break even, when offering an installation, the section will help the user to compare if the calculation was reasonable.

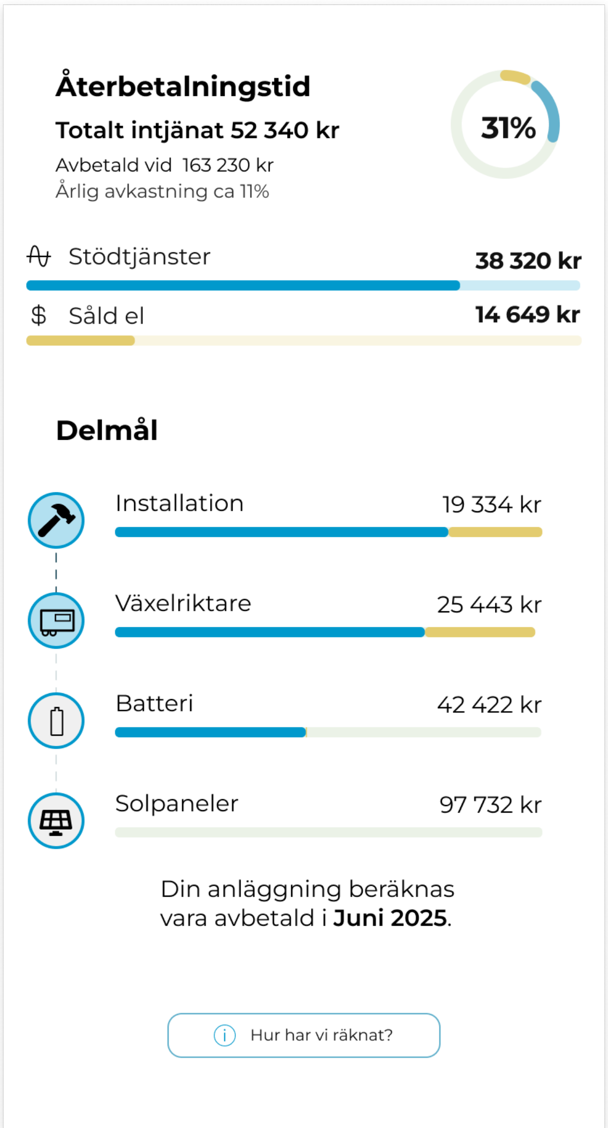

Figure 8.22: Repayment period graph

8.5 Profile

The profile page contains most necessary settings that a user can perform. This involves tasks such as entering bank details and orientation of PV. It can also include options to adjust battery charging and discharging thresholds, set energy-saving modes, or schedule specific operations. This page was however not given much attention, as the settings would differ depending on implementation.

8.6 Overlays

The overlays in Figure 8.23 were created to further educate the user but also to give explanations of how calculations were done as well as of difficult concepts. These are two excerpts from the prototype, where one explains FCR-D and the other explains the constituent costs of bought electricity that is involved in a graph. Even though it is best if the system doesn't need explanation, it was deemed necessary to provide additional information about some features.

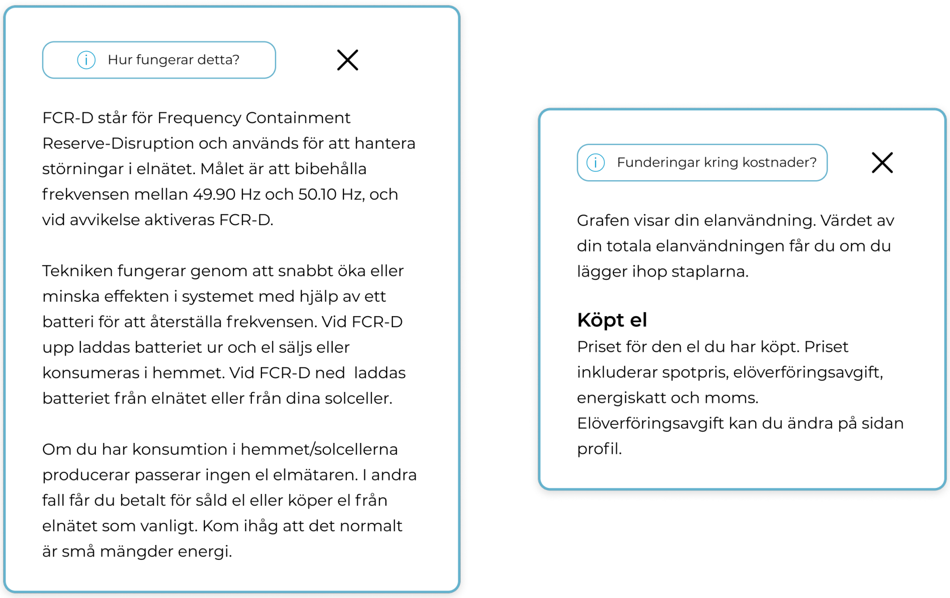

Figure 8.23: Suggested notifications

8.7 Notifications

One user expressed: "I want to see that my investment is used". Other users expressed that they would appreciate some sort of feedback when the system is doing a contribution. This is understandable as the ancillary market in residential context is a novelty. To cater for user goal 13, *Ability to see that the battery is performing work*, two notifications (Figure 8.24) were created that would inform the user of contributions to the grid. The first one notifies when a contribution is made. The second notification provides a summary of today's contributions.

The last notification (Figure 8.24) was designed to let the user know if the system for some reason is offline. This is beneficial for the user to know, since the battery does not provide income if it is offline. By being notified, the user can take action to get the battery back to an online status.

Figure 8.24: Suggested notifications

8.8 Fulfillment of User Goals

Most of the user goals are fulfilled by several different features in the prototype. This is an effect of providing a condensed overview page of the prototype as the landing screen. Information regarding the economy is also presented in multiple pages (for instance energy flow and economy). The information fits the context of both pages and the user can choose which page to visit.

In the previous sections, the main user goal of the feature has been presented. In Table 8.1 each user goal is listed together with the feature(s) that fulfills the goal.

Table 8.1: Fulfillment of user goals by features

User goal	**Fulfilled by**
1. Cater for mobile as well as desktop and tablet devices	The prototype
2. Ability to quickly access current flow of energy eg. current production and consumption	Overview - Right now 8.1.0.1
3. Ability to see historic production and consumption	Energy flow - Solar panels 8.2.1 Energy flow - Electricity usage 8.2.3
4. Ability to see level of self consumption	Energy flow - Usage of solar electricity 8.2.2 Energy flow - Electricity usage 8.2.3
5. Ability to indicate whether solar panels are functioning properly or not	Overview - Solar panels 8.1.0.2 Energy flow - Solar panels 8.2.1
6. Ability to see economy related to solar panels	Overview - Economy 8.1.0.4 Energy flow - Solar panels 8.2.1 Economy - Income 8.4.1 Economy - Repayment period 8.4.5
7. Ability to see energy consumed and cost of usage	Energy flow 8.2
8. Ability to see solar energy consumed	Energy flow - Usage of solar electricity 8.2.2 Energy flow - Electricity usage 8.2.3 Energy flow - Home usage 8.2.4
9. Ability to plan for optimal time to consume electricity	Overview - Spot price 8.1.0.5 Energy flow - Solar panels 8.2.1

User goal	Fulfilled by
10. Ability to see status of battery eg. state of charge	Overview - Battery 8.1.0.3 Battery page 8.3 Battery - Overlay 8.3.1
11. Ability to see battery service setting eg. type of ancillary service	Overview - Battery 8.1.0.3 Battery page 8.3
12. Ability to see battery activity with regards to ancillary services and Currently	Battery page 8.3
13. Ability to see that the battery is performing work	Battery page 8.3 Notifications 8.7
14. Ability to see income generated by facility and from ancillary services	Overview - Economy 8.1.0.4 Economy - Income 8.4.1
15. Ability to see a summary of costs and income	Economy - Results 8.4.3 Economy - Economic summary 8.4.4
16. Ability to see a forecast of return on investment	Economy - Repayment period 8.4.5
17. Ability to see facility in regards to sustainability	Battery page 8.3
18. Ability to make decisions based on the most sustainable outcome	Overview - Solar panels 8.1.0.2 Energy flow - Solar panels 8.2.1 Energy flow - Home usage 8.2.4

9

Future Design Work

This chapter includes ideas and found user goals and needs for future design work.

9.1 Power Tariffs

As power tariffs will be introduced at latest on the 1:st of January 2027 (Energimarknadsinspektionen, 2022), it will most likely play a role in CheckWatt's VPP Currently. Depending on the electricity network company that is providing the electricity, the tariffs can differ. This means that a future design must have a way of incorporating each user's respective tariffs in order for the user to get the information needed. At the time of writing there is a discrepancy between DSOs in the models for power tariffs.

9.2 Flexible Energy Resources

During the design of the prototype, limited attention was given to potential alternative energy resources that could function similarly to residential batteries in the future. This was mainly because there were no integration options available at the time of development. However, the market for providing grid flexibility is expanding rapidly, and it is likely that EV-charging and heating systems could be part of Currently and provide flexibility services in a not so distant future. As these new functionalities emerge, it is essential to address the evolving user goals and requirements. The following user research findings outline the needs and goals related to EV-charging found throughout the user research. Not enough attention was put on the user goals related to heating systems and further research within this area is needed for future development.

User goals formulated for future integration of vehicles to Currently:

1. Ability to see energy data related to charging
2. Ability to automate charging in regards to PV-production, cost of electricity and power tariffs
3. Ability to see the charge plan for automated charging (what hours with what power)
4. Ability to see charge duration and set time for completion

5. Set power for charging
6. Ability to override automated charging
7. Ability to see kWh represented in km
8. Ability to see if the car is connected to the charger
9. Ability to set max state of charge
10. Ability to see if and when ancillary services are delivered
11. Ability to set lowest acceptable state of charge

9.3 Communicate the Importance of Ancillary Services

The prototype communicates the importance of the batteries in regards to ancillary services and Currently, user goal 12 *Ability to see battery activity with regards to ancillary services and Currently*, by showing how it aided in getting the frequency back to normal levels. But it is not compared to the whole system perspective, as in what is the value of Currently in comparison to the rest of the actors on the grid providing ancillary services. Including this could further increase the sense of community and highlight its importance. It is however as of now difficult to find data for such calculations, but it is being researched by others and when such data can be turned into relatable numbers it could be beneficial to include.

10

Discussion

This chapter presents a discussion of the master's thesis as well as its process and results.

10.1 Research Through Design

RtD has been increasingly recognized as a valuable approach for advancing knowledge in various design disciplines, such as interaction design, user experience design, product design, and service design. While it offers unique strengths, such as the ability to tackle complex design problems and generate new knowledge through the act of designing, it also presents challenges and limitations, including concerns regarding the validity and generalizability of findings, the subjective nature of the design process, and the difficulty of documenting and disseminating design knowledge.

10.2 Working with Quick Iterations

The early phases primarily used the method of ten minute iteration subsection 4.4.2. The benefit of this methodology was that the design could evolve quickly. Ideas that proved to gain comprehension from respondents were selected to continue evolving and ideas that proved to be difficult to understand were left behind. This type of parallel development and testing proved to be beneficial for the process. Evolution happened quite swiftly and dead ends were eliminated in an early phase.

A great deal of care does need to be taken when working under these conditions. The evaluation with respondents was done with relatively few individuals and their thoughts and suggestions can impact the design in a disproportionate way. This requires the designers to take great care when valuing the feedback. Each individual has unique needs and preferences, and what works well for one person may not work as well for everyone else. As the designers had built knowledge about the needs and requirements from other users, it was their job to compile the ten minute iteration respondents' feedback together with other users' needs.

Being critical of each person's opinions in the tests is also of importance. This means looking beyond the immediate feedback and thinking about why they're providing the feedback they are. This is true both for the ten minute iterations as well as the user research in the prepare phase section 4.2.

Each change in the design within a round of iteration was discussed between the designers. The aim of the discussion was to value the just received feedback and weigh the options of potential design solutions in order to create a design that would fit users encountered previously. The respondents in the ten minute iterations also varied over the rounds. This was a decision in order to try and eliminate the risk that a single respondent would get too large of an impact on the design. Most of the respondents in the ten minute iterations were engineering students. This could've perhaps influenced the test results as these students generally have a strong knowledge of energy related concepts.

Ultimately, it is a balancing act when designing for several different types of users, whether it is done in quick or slow iterations. The training and proficiency of human centered design researchers is valuable in this setting.

10.3 Impact of Prototype Tool on Testing

This section provides a discussion of how the prototype could have impacted the testing.

10.3.1 Figma

Figma as a design tool has its benefits and drawbacks. In this thesis, the benefits outweigh the drawbacks. As it is a browser-based tool, and as such, it can sometimes suffer from performance issues when working with large files or complex projects. This might cause slower response times (lag). This issue was experienced by one participant in the supervised testing, possibly skewing the results of the test. It is also possible that this issue occurred in the unsupervised tests, it is however uncertain if this affected the participants' experience.

Another drawback is the lack of logic and user input booleans. When working with different types of graphs, especially the Home usage graph, it is not feasible to build all possible combinations of filters. If there was built in logic, this graph could have been generated in real time. Instead, the prototype had a static graph showing all filters turned on, making it cluttered.

Finally, the prototype was not developed far enough to have all the interactions a user might expect. For instance, making it possible to select any date would lead to an extensive development of many similar screens. A respondent in testing might be affected by this. In the unsupervised testing it is possible that users tried to click items that would contain an interaction in a real app, but was not implemented in the prototype. This could have affected respondents, causing them to abandon a task or skewing their rating of the prototype. One solution would be to implement all tappable areas but point them towards a message telling the respondent that the interaction is not implemented.

10.3.2 Using Fake Data for Energy

Fake data for electricity consumption and production was used to generate graphs and numbers in the prototype. Even if there was access to real data from real systems, it was not an option to use this data. It belongs to a person and can be viewed as personal data. Instead, mock data was produced with inspiration from real data. It is difficult to keep this data consistent between different graphs and numbers. One change in the data created a ripple effect on multiple graphs in the prototype. Efforts were made in order to try to keep this data consistent throughout the prototype. However, some of the participants in user testing spotted inconsistencies. In the supervised remote testing, the researchers could ask the participant to overlook this shortcoming of the prototype, but it could have affected the results of the unsupervised testing.

10.4 Communicating Concepts with LoFi Prototypes Requires Training

The development stage of the project started out with sketching out different screens that would satisfy the user goals and then get feedback on the design. The sketches would then develop into digital wireframes with low fidelity where the same procedure took place. During this phase of creating LoFi mockups it was found difficult to get the user to focus on the concept rather than on the fidelity of the prototype. To compensate for users pointing out irrelevant things on a concept, mockups of higher fidelity were created. It is always difficult to put an end to the refinement process and finding the right amount of fidelity requires training.

10.5 Supervised and Unsupervised Testing

The project utilized two different forms of user testing in order to get a wider range of feedback - supervised and unsupervised. The advantage of doing supervised testing is the ability to control most situations and faults appearing throughout the test. However, this puts pressure on the researcher to not influence the tester. The presence of a facilitator or researcher may influence user behavior, leading to a potential bias in their actions or feedback. Users might feel conscious or perform differently than they would in a natural setting and it could seem as the tester is rating the researcher rather than the prototype.

The supervised user test started with letting the user explore the overview page while thinking aloud. In order to get a more real interaction of the first usage of the prototype, it could've been beneficial to let the user instead familiarize with the whole prototype before starting the test. This would perhaps mimic a realistic interaction, however would perhaps limit the testing of learnability as the user then would've already seen most of the pages. Learnability was however tested in the unsupervised test where the sample size was larger.

10.6 Comparing Battery Tasks from an Economic Perspective

It would be possible to visualize and compare forecasts with regards to revenue for different battery tasks, such as saving solar, EA, PS or ancillary services. The system currently chooses the task that provides the largest revenue for the user. This has been an easy task over the past two years, since the ancillary service of FCR-D by far has produced the most income 95% of the time. This could change in the future. If that is the case, it would be possible to provide a forecast over the income generated by the BESS. This is however not without difficulties. Such a decision would have to be done several days in advance, due to the trading of ancillary services and electricity. It would include making forecast models over each type of task and their market. If the models were 100% correct, it would not pose a problem. But if the models are not correct and a decision is based on the model, the user could be dissatisfied with the outcome. The logic behind the models could be transparent for the user, but that would probably include revealing intellectual property of a company. Further, these models will probably be difficult to develop and get correct. One aspect would be the weather (affecting PV production), of which we currently have well developed models that are not correct 100% of the time. Models of other entities might prove as difficult to develop.

If a feature of this kind is to be implemented, it is suggested to visualize the outcome rather than a forecast. That way the calculations are always correct and the user can make its own assumption about the near future, thus not laying any blame on the design.

10.7 Sustainability Comparison

The prototype does not include any comparisons to sustainability aspects such as CO_2 equivalents (which is common in similar applications) but rather focuses on the generation of value that resources create. Highlighting the economic value of the sold electricity rather than showing saved CO_2 or similar is meant to encourage selling generated solar electricity. As long as there is non-RES energy present in the grid it is always better if it can be replaced by solar energy as that would lower the overall environmental impact. Solar panels already have a carbon footprint, and the more they replace energy from other sources, the better. This also means that the electricity grid likely will not need to be expanded to the same extent. It also promotes the development of more renewable energy resources. Designing for behavior change can bring backlash effects, such as households using more energy than they need because it is low CO_2. It was therefore deemed important to not encourage a behavior that would not be beneficial from a system standpoint. For the individual household it could of course feel nice to be self-sufficient on electricity from one's battery and solar panels, but from a holistic standpoint it could be more beneficial if the energy could be shared. The information in the prototype contains enough information for a user to optimize their energy consumption in regard to PV production and spot price, but does not state a total sustainability figure (such as offset CO_2). A total sustainability figure could encourage a user to be even more sustainable but it could also be used to justify unsustainable decisions.

10.8 Gender Representation

The solar/battery community is heavily dominated by men in their middle age. As diffusion of these systems currently is in the early adopters phase, this group is quite homogeneous. They tend to have a strong interest in technology, and a higher level of disposable income.

This homogeneous group of early adopters often has a keen understanding of the technology behind solar and battery systems. They are likely to engage in online forums, social media groups, and other communities where they can discuss their experiences, share knowledge, and provide support to one another. As the solar/battery technology continues to diffuse, it is expected that a more diverse group of individuals will become interested in adopting these systems. This shift has not happened yet though.

As this homogeneous group also were the majority of participants in both the user research as well as the user testing activities, the design might be over-fitted to their needs and opinions. The issue with homogeneity was present in the designer's thoughts throughout the project. The personas developed was used partly as a remedy for this issue. It is however not a guarantee for an unbiased design towards gender or group homogeneity. Further evaluation on the design with participants are needed to verify that the design is unbiased.

10.9 Users Background Knowledge of Ancillary Services

It is evident from testing that users need some background knowledge of ancillary services in order to answer *all* questions that might appear when using the application. One such question could be "Why can't I control my battery to some extent myself, when performing ancillary services?". Explaining the reason behind this is quite complicated and the explanation will be different based on how the electricity production and consumption works at the user's home.

More information about how ancillary services work in general could be included in the app. This information would however require long texts explaining the power grid and what the user needs to find out about their home in order to themselves make the conclusion that answers the question. The design can however be used without answering these questions, while providing the user information about their part in the VPP, PV and BESS. The authors of this thesis suggest that extending knowledge of the power grid should be presented in contexts outside the prototype that could be more suitable for this type of information. One such information channel could be the web page of the company providing the aggregation of BESS into a VPP.

The concept of a distributed VPP is something that users also need to understand to some extent while enrolled. Action has been taken on the battery page in order to visualize that their BESS is a part of a larger network. The actual concept of a VPP is however not highlighted. There could be design improvements in this area. It is however deemed complex to communicate what a VPP does at every given moment, as the tasks are ever changing based on the market and other external factors. A design to communicate the concept of a VPP on a mobile phone screen might raise more questions than answers.

10.10 Ancillary Services as a Solution

At the time of writing, ancillary services are required in the grid. The Swedish TSO, Svenska Kraftnät, has increased their request for ancillary services since their introduction in 2014 and added new types of ancillary services to the market.

It could be argued that if each power grid connection point had a battery, a more stable load to the power grid would be present without power peaks. However, this would require that each point had some kind of energy storage system (ESS). By aggregating energy sources into a VPP the needed quantity of ESS:es is lowered, causing less environmental impact. However, an ESS at one connection point not aggregated in a VPP will have positive benefits on its surrounding connection points. The true answer lays in the research field of modeling power grids and connections. This is an extensive field and not in the scope of this thesis.

10.11 The Feeling of Self Sufficiency

Several respondents not connected to a VPP spoke about the feeling of being self-sufficient on electricity. These users typically have solar panels and a BESS connected to their home. Depending on their location and performance of their system, they can be self-sufficient on electricity large parts of the year. These systems are not typically decoupled from the grid. A grid decoupling or off grid mode is associated with a significant amount of investment. In other words, they still rely on a grid connection to ensure a stable system.

Enrollment in a VPP usually means that the user looses control of his/her battery and becomes more reliant on the grid. They can not save solar electricity for later use in their battery as they did before connecting to a VPP. It is hard for an aggregator to compete with the feeling of being self-sufficient.

There are two main arguments for connecting to a VPP. The first one is economy. On the current market, the ancillary services performed by a VPP is very profitable. If a user has invested in energy storage out of economic reasons, this argument is beneficial. The second argument is related to sustainability from a systems perspective. It is undoubtedly beneficial from a sustainability perspective if a home can be self-sufficient on electricity in parts of the year. It is however even more sustainable if a home can enroll its battery in a VPP. Put in simple terms, if a battery is connected to a VPP, it can be seen as shared among several homes, instead of only connected to a single home. On the other hand, if a home is self-sufficient on electricity it does not pose a load on the power grid. This is however only beneficial for regulating power up. Ancillary services regulate both up and down.

Potentially, there is a solution to combine a VPP with self sufficiency. As mentioned in section 2.1, the power available from a BESS is of most importance. A BESS usually has the possibility to split its power. One scenario could be to provide half of the battery power for ancillary services and the other half for self sufficiency. This would generate a lower income for ancillary services but it would cater to the feeling of being self-sufficient on electric power. This use case is however not something that would impact the design in this thesis, but rather something to implement in the software that controls the VPP.

10.12 Why V2X was not Studied

The concept of vehicle to everything (V2X) was encountered several times along the project. V2X makes it possible to discharge a car's battery to the grid and could work similarly to a residential BESS. The design has however not taken V2X into account. This is mainly because V2X has not gained any significant market penetration in Europe. At the time of writing, it is not possible to buy a V2X enabled wall box for EV charging in the residential market.

There could be several applications for V2X in the future. One such application would be to have the EV perform ancillary services. There are ideas about how this could be incorporated in the design, but it has not been implemented in the prototype or tested. It would have been possible to design and test, but a user base with real world experience from V2X applications would not have been available. The authors recommend that such a design should be implemented and tested in the future, if there is a profitable market for using V2X in ancillary services. A requirement specification for V2X integration has however been presented in section 9.2.

10.13 Societal and Ethical Aspects

This section presents the discussion of societal and ethical aspects of this thesis.

Societal

When a homeowners battery is aggregated and provides support services, it cannot be utilized for other purposes such as storing solar electricity. Since solar energy is often perceived as free energy, this limitation could potentially result in an escalation of consumption when solar panels are actively producing electricity that cannot be stored in the battery.

As the energy system is transitioning toward an increasing amount of RES, ancillary services become more important. Smart control of BESS enables the grid to cope with an increasing amount of intermittent electricity production, potentially providing positive societal aspects with less fluctuation in both energy prices as well as outages and electricity quality.

Ethical

When performing user interviews and tests, the integrity of the participant is an ethical aspect that needs to be taken into account. Participants have been given the option to abandon the interview/test at any time and have their data deleted. Data has been stored in an anonymized format and on servers that reside in the EU.

11

Conclusion

The purpose and aim of this thesis is to identify user goals and develop an interface for residential customers enrolled in a VPP. These goals are fulfilled with a high-fidelity interactive prototype, created in a human centered design process. The prototype has been verified by supervised and unsupervised user testing, answering guiding RQ 1.

The thesis has gone through four different phases in a human centered design process. Each phase has had specific goals that have been fulfilled.

In the preparation phase, the goal was to get a comprehensive market overview, as well as guidelines for communicating quantities of energy. A benchmark was done where 21 mobile and 14 desktop applications were investigated. The benchmark contributed to the design work in later phases. A literature study on how to communicate energy quantities concluded that it is best not to abstract energy into something more familiar. Studies show that energy quantity is a concept that is quite easy to learn and the effects of learning stay over time. This result answers guiding RQ 2.

In the explore and analyse phase, the goal of defining and specifying user goals and needs was achieved by conducting user research in the form of interviews and observations and analyzing the results. The requirement specification created worked as a foundation for the build phase. A requirement specification for future design work for V2X applications was a side effect of the user research and testing and is presented in section 9.2.

The goal of the build phase was fulfilled by creating a high fidelity prototype that would satisfy the formulated user goals and needs. The project used a quick iteration method outlined in subsection 4.4.2. The method allowed for fast evolution of the design, while keeping the user needs central in the work.

The goal of the test - rebuild phase was to create a high fidelity prototype to facilitate user testing. This was done through an iterative design process with incremental changes of the low fidelity prototype until it was deemed ready for testing. The prototype was used for both supervised and unsupervised testing.

The testing in general showed good results but some parts of the interface could be improved. The improved interface is presented in chapter 8, Final Design.

RQ 3 asked how information can be presented to encourage sustainable behavior.

This information can have backlash effects, discussed in section 10.7. It was decided to highlight the economic value of one's facility in order to not encourage excess usage of electricity produced from solar panels.

In conclusion, this thesis has fulfilled the purpose and aim, as well as the goals of each phase in the design process and created potential improvements to the user experience of battery owners providing ancillary services connected to a VPP. By making the experience of being a member of a VPP more attractive, this thesis indirectly contributes to a more sustainable society.

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A

Appendix A: Explore and Analyze

A.1 Interviews and observations

Demografi

Ålder

Kön

Elbil

Hur länge har du haft solpaneler?

Vilket batteri, hur stor solcellsanläggning?

Hur intressant är avbetalningstid?

Hur van är du vid branschspecifika koncept? (energikunskap)

Uppvärmning

Miljöintresserad?

Befintlig kund - Får vi spela in?

Hur länge har du varit ansluten till CheckWatt? Motivation bakom anslutning?

Hur mycket använder du dig av EnergyInBalance?

Använder du EIB på mobil/dator och eller padda?

Hur upplever du EnergyInBalance?

Vad tittar du på för grejer i EIB? Dela skärm och visa hur du använder?

Vad saknar du i EIB?

Är det något som är svårt att förstå?

Intresse av att styra batteriet själv? Användandet av egenproducerad el vs bidra till nätet? Störst incitament? (ekonomi eller miljö/hållbar omställning)

Exporterar du någon data från EIB? I så fall: Vad gör du med datan?

Vilka flikar använder du i EIB?

Vad använder du för system idag? T.ex. titta på produktion av solel.

Använder du någon app från t.ex. el handelsbolag?

Har ditt intresse/kunskap om elnät/stödtjänster förändrats sedan du anslöt dig till CheckWatt?

Om intresserad kund, men ej ansluten

Varför är du intresserad av CheckWatt?

Vad vill du veta om systemet?

Vad har du för förväntningar på gränssnittet? (Alltså EIB i stort)

Vad använder du för system idag? T.ex. titta på produktion av solel.

Använder du någon app från t.ex. Elhandelsbolag?

B

Appendix B: User Testing

B.1 Supervised Remote Testing Tasks

Uppgifter

Uppgift 1

Kolla lite på startsidan och berätta hur du hade använt den. Du får klicka på saker om du vill.

Uppgift 2

Du ska åka iväg med din elbil efter jobbet i morgon. Du ska göra en längre resa. Kolla om du behöver förbereda något inför resan. Ledtråd 1: Behöver du ladda bilen? Ledtråd 2: När ska du ladda bilen?

Uppgift 3

Du sänkte värmen med en grad i förrgår. Nu är du nyfiken på hur mycket energi det gick åt igår till värmen. Kolla detta.

Uppgift 4

Du vill hålla koll på när mycket energi används. Ta reda på vilken timme som kostade mest pengar idag. Du behöver bara svara med vilken timme det är, inte vad den kostade.

Uppgift 5

Ditt batteri stöttar elnätet. Du är nyfiken på om batteriet gör något. Kolla detta.

Vad tror du händer om man tappar på dagens insatser?

Uppgift 6

Fakturan för februari kommer snart. Du funderar över din ekonomi för februari med tanke på elkostnader. Kolla hur det gick i februari. Vilken är den valda vägen till kostnad 12:e feb?

Hur hade du använt grafen Hemmets energianvändning på riktigt?

Övrigt prat Finns det något i dina andra el-appar som du saknar i denna?

Var det någon funktion som överraskade dig, positivt eller negativt? Vad tycker du om utseendet på appen? Hur upplever du navigationen?

B.2 Supervised User Test Semantic Word Scale

Figure B.1: Semantic word scale results

B.3 Unsupervised Test

Preview mode: No answers will be saved.

Användartest av framtida CheckWatt-app

Hej!

Först och främst, tack för att du tar dig tid för att göra detta test!

Vilka är vi?

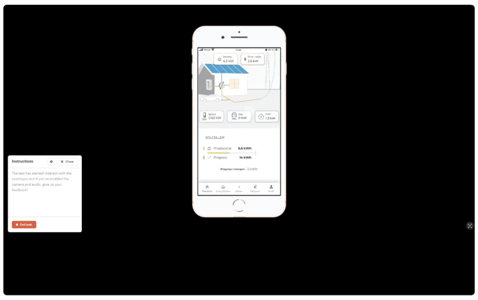
Vi är två studenter som skriver exjobb på Teknisk Design och Interaktionsdesign på Chalmers och CheckWatt. Vårt mål är att designa en app för CheckWatts kunder.

Om dig

Du är helt anonym när du gör testet. Ingen data sparas som kan användas för att identifiera dig, om du inte väljer att fylla i en e-postadress i slutet.

Skärminspelning

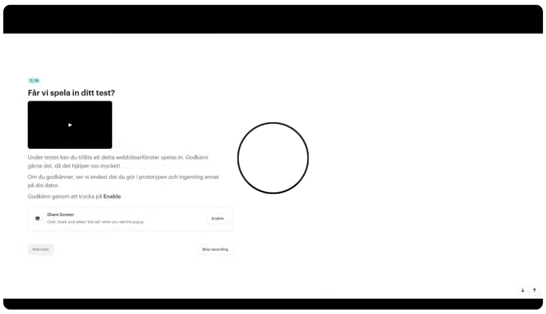
I nästa steg får du en fråga om vi får spela in ditt test. Godkänn gärna detta då det hjälper oss mycket i utvecklingen! Till höger ser du ett exempel på vad vi ser vid en skärminspelning.



Get started

Preview mode: No answers will be saved.

Får vi spela in ditt test?



Under testet kan du tillåta att **detta webbläsarfönster** spelas in. Godkänn gärna det, då det hjälper oss mycket!

Om du godkänner, ser vi endast det du gör i prototypen och ingenting annat på din dator.

Godkänn genom att trycka på **Enable.**

I videon ovan ser du stegen för att godkänna inspelningen.

Share Screen

Click 'share' and select 'this tab' when you see the popup

Enable

Start test

Skip recording

Preview mode: No answers will be saved.

Könsidentitet

Välj ett av alternativen

- Man
- Kvinna
- Ickebinär
- Annat alternativ
- Osäker
- Vill ej svara

Go to next step

Preview mode: No answers will be saved.

Hur hittade du hit?

Facebookgrupp CheckWatt Kunder

Facebookgrupp Fem Solar

Fick länken i ett meddelande

Fick länken av en kompis

Go to next step

Preview mode: No answers will be saved.

Har du solpaneler och batteri?

Välj ett av alternativen

- Både solpaneler och batteri
- Bara solpaneler
- Jag har varken solpaneler eller batteri
- Vill inte svara

Go to next step

Preview mode: No answers will be saved.

Känner du till stödtjänstmarknaden?

Exempel på stödtjänster är FCR och FFR.

- Ja, ganska bra
- Ja, litegrann
- Nej
- Vill inte svara

Go to next step

↓ ↑

Preview mode: No answers will be saved.

Är du ansluten till CheckWatts tjänster?

Välj ett av alternativen

- Ja
- Nej
- Nej, men jag har skickat en intresseanmälan
- Nej, men jag är intresserad
- Vill inte svara

Go to next step

Preview mode: No answers will be saved.

Hur ofta kollar du i appar relaterade till energi?

Ex. Kollar dina solceller, din elförbrukning, spotpris osv.

- Flera gånger per dag
- En gång per dag
- Några gånger i veckan
- En gång i veckan
- En gång i månaden
- Mer sällan
- Aldrig

Go to next step

↓ ↑

Preview mode: No answers will be saved.

Så här fungerar testet

Det här testet består av flera steg.
Du kommer att få en uppgift att utföra i varje steg.

Kom ihåg att detta är en prototyp och det kanske inte går att klicka på allt du förväntar dig.

I slutet av testet kommer du att få klicka dig runt i app-prototypen så länge du vill.

Go to next step

↓ ↑

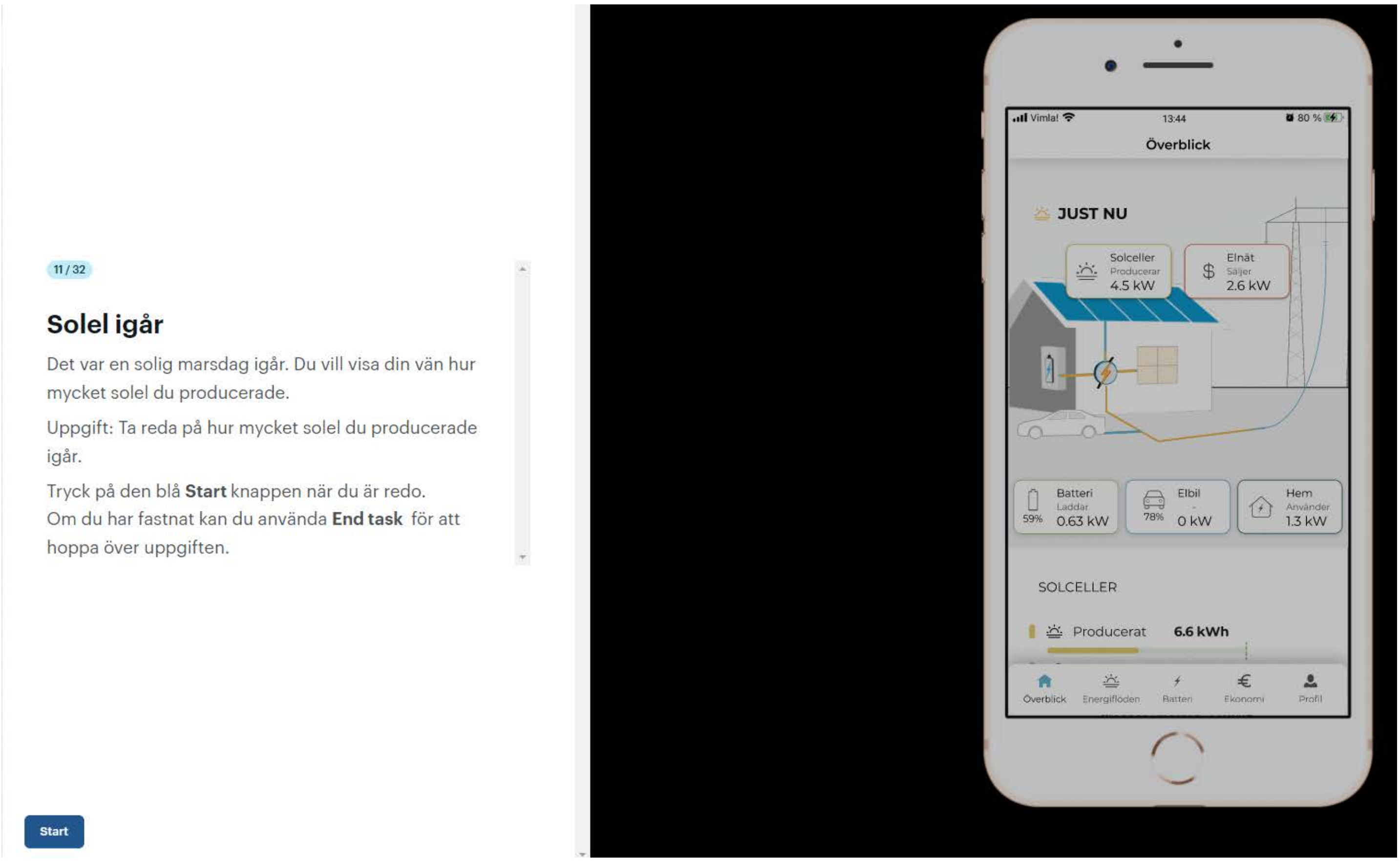
Preview mode: No answers will be saved.

Scenario

När du gör testet så låtsas vi att du är följande person.

Du bor i villa och har solceller, elbil och ett Sungrow batteri. Ditt batteri hjälper till att stötta elnätet, när det behövs. Klockan är 13:44 den 8:e mars.

Go to next step


11 / 32
Solel igår
Det var en solig marsdag igår. Du vill visa din vän hur mycket solel du producerade.
Uppgift: Ta reda på hur mycket solel du producerade igår.
Tryck på den blå Start knappen när du är redo.
Om du har fastnat kan du använda End task för att hoppa över uppgiften.
Start
Vimla!
13:44
80 %
Överblick
JUST NU
Solceller
Producerar
4.5 kW
Elnät
Säljer
2.6 kW
Batteri
Laddar
59%
0.63 kW
Elbil
78%
0 kW
Hem
Använder
1.3 kW
SOLCELLER
Producerat
6.6 kWh
Överblick
Energiflöden
Batteri
Ekonomi
Profil

12 / 32

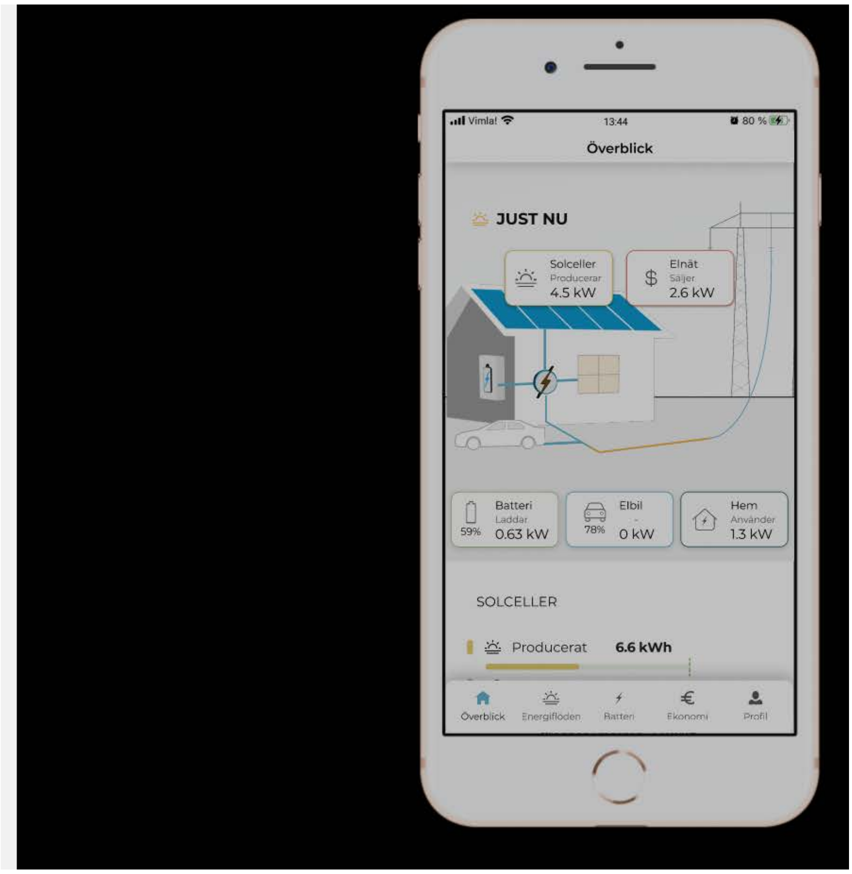
Solelsproduktion i morse

Din granne säger att hens anläggning producerade 0.2 kW klockan 8 i morse och undrar hur mycket din anläggning producerade samma tid.

Uppgift: Ta reda på vilken effekt dina solceller gav kl 8 **idag**.

Tryck på den blå **Start** knappen när du är redo.
Om du har fastnat kan du använda **End task** för att hoppa över uppgiften.

Start



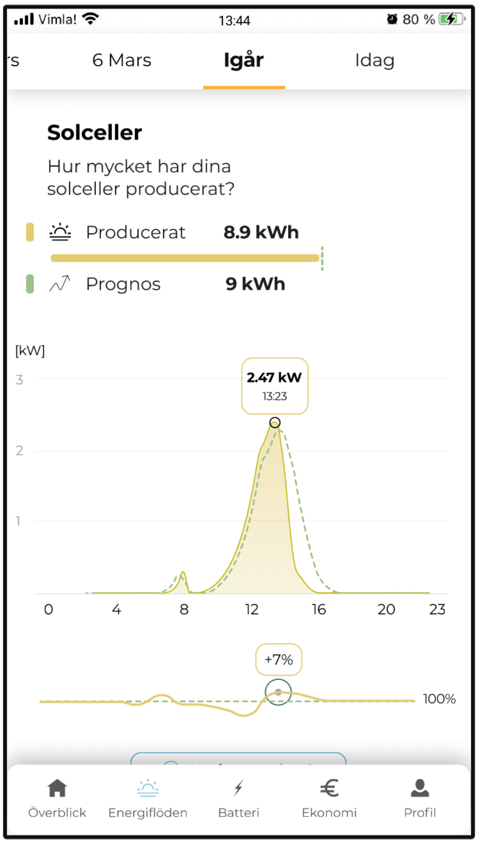
Preview mode: No answers will be saved.

Solceller

Vad tror du +7% betyder, som står vid den nedre linjen?

Enter your answer

Go to next step

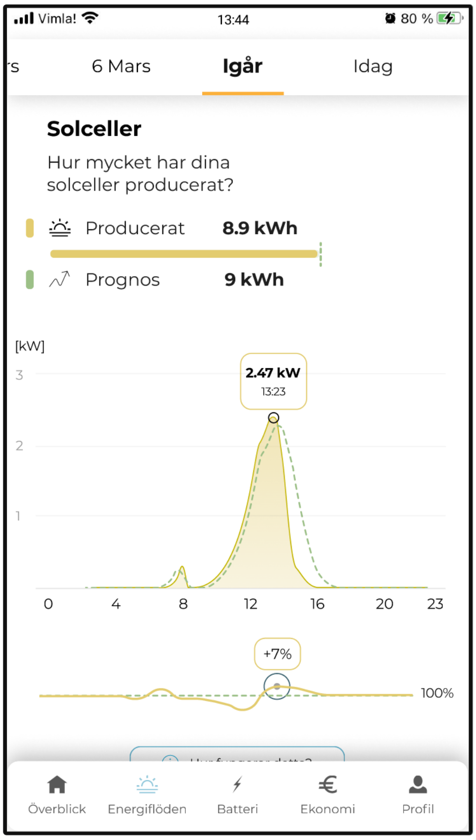


Preview mode: No answers will be saved.

Detta är en prognos över din solelsproduktion

+7% är hur väl prognosen stämde överens med faktisk produktion kl 13:23.

Go to next step



Preview mode: No answers will be saved.

Prognos solelsproduktion

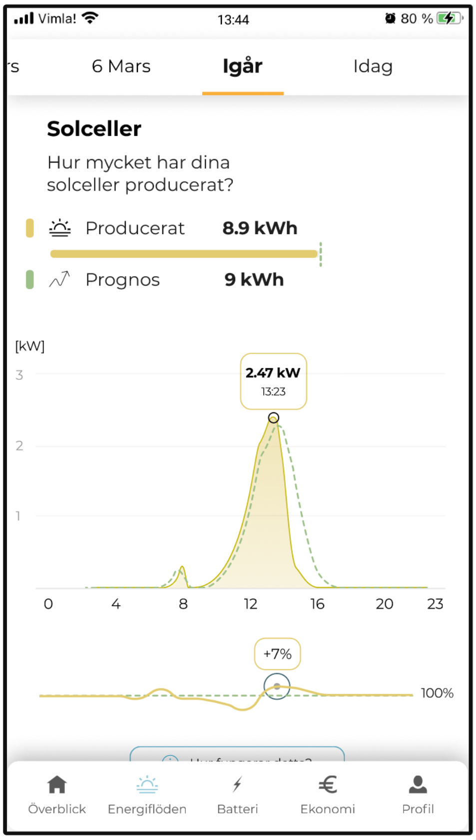
Hur användbar tycker du prognosfunktionen är?

1 2 3 4

5 6 7

Inte användbar — Mycket användbar

Go to next step



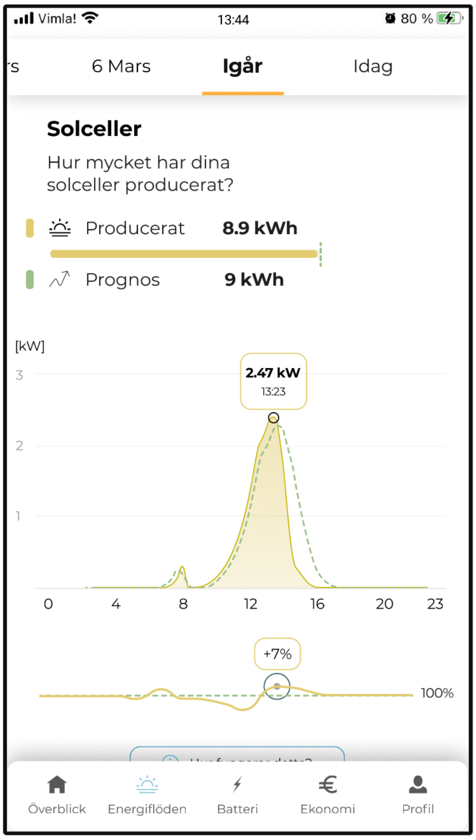
Preview mode: No answers will be saved.

Prognos solelsproduktion

Har du några övriga tankar kring funktionen?

Enter your answer

Go to next step



Preview mode: No answers will be saved.

Elanvändning

Titta på filmen bredvid. Vart kommer strömmen ifrån?

Choose as many as you like

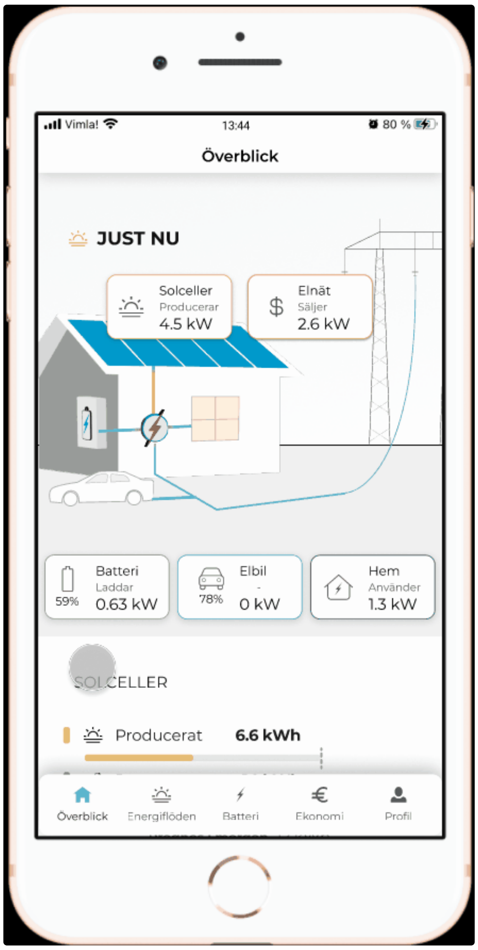
Elnätet

Batteri

Solceller

Vet inte

Go to next step



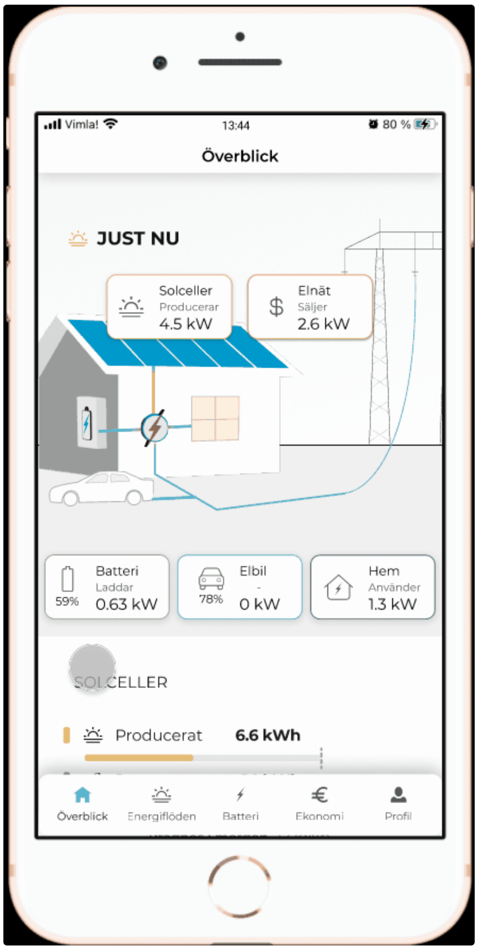
Preview mode: No answers will be saved.

Elanvändning

Övrigt att tillägga kring sidan som visas?

Enter your answer

Go to next step



Preview mode: No answers will be saved.

Växla mellan kWh och kr

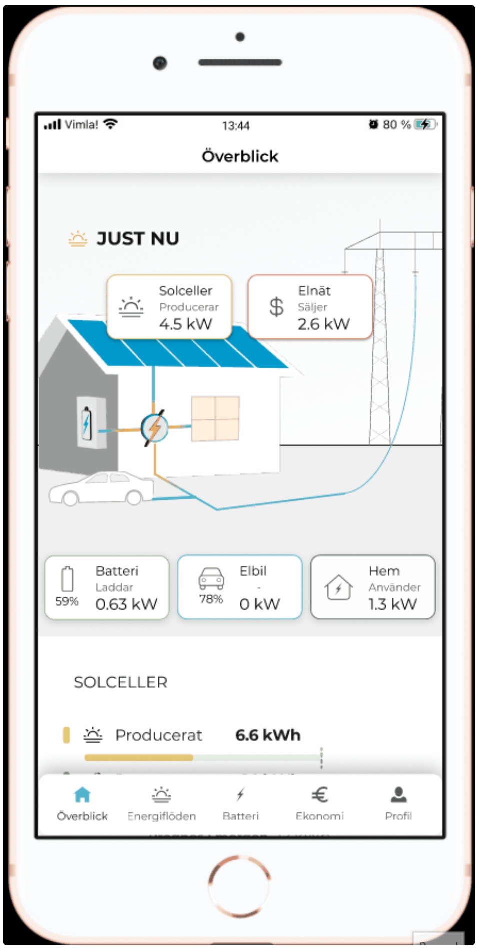
Se animationen bredvid. Den här funktionen finns tillgänglig i de flesta grafer.
Vad tycker du om funktionen att växla mellan kWh/kr i grafen?

Priset i kronor inkluderar spotpris, elöverföringsavgift, energiskatt och moms. Kostnaden för elöverföringsavgift kan ändras i appen.

1 2 3 4
5 6 7

Inte användbar — Mycket användbar

Go to next step



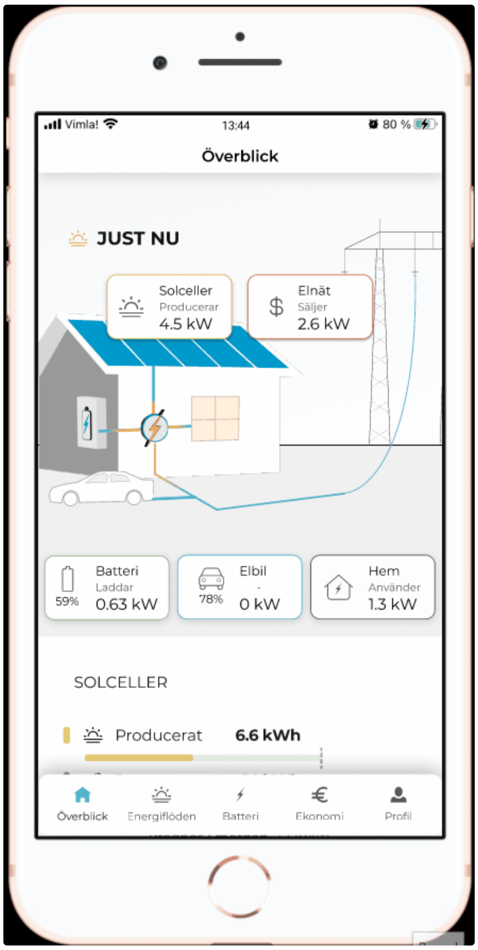
Preview mode: No answers will be saved.

Växla mellan kWh och kr

Har du något övrigt att tillägga om funktionen?

Enter your answer

Go to next step



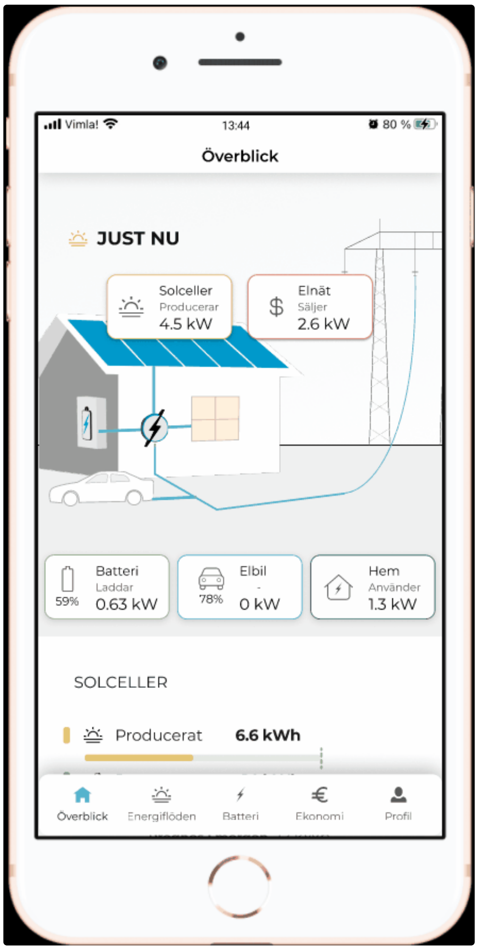
Preview mode: No answers will be saved.

Överblick just nu

Klicka i de påstående som stämmer överens med bilden.

Choose as many as you like

- Dina solceller producerar 4.5 kW
- Dina solceller producerar 2.6 kW
- Du säljer 2.6 kW till elnätet
- Du köper 1.3 kW från elnätet till hemmet
- Du använder 1.3 kW solel i hemmet
- Batteriet laddas ur med 0.63 kW
- Batteriet är på uppladdning med 0.63 kW
- Vet inte



Go to next step

Preview mode: No answers will be saved.

Överblick just nu

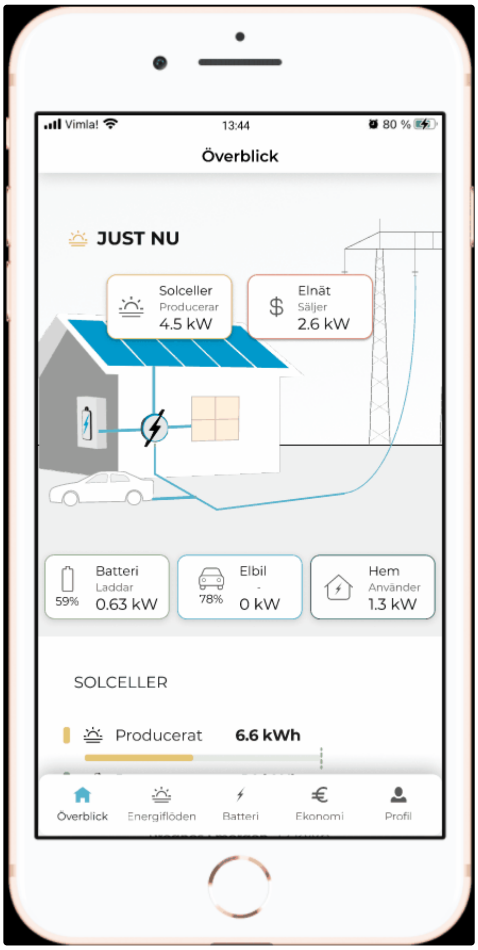
Vad tycker du om översiktsbilden energi just nu?

1 2 3 4

5 6 7

Otydlig Tydlig

Go to next step



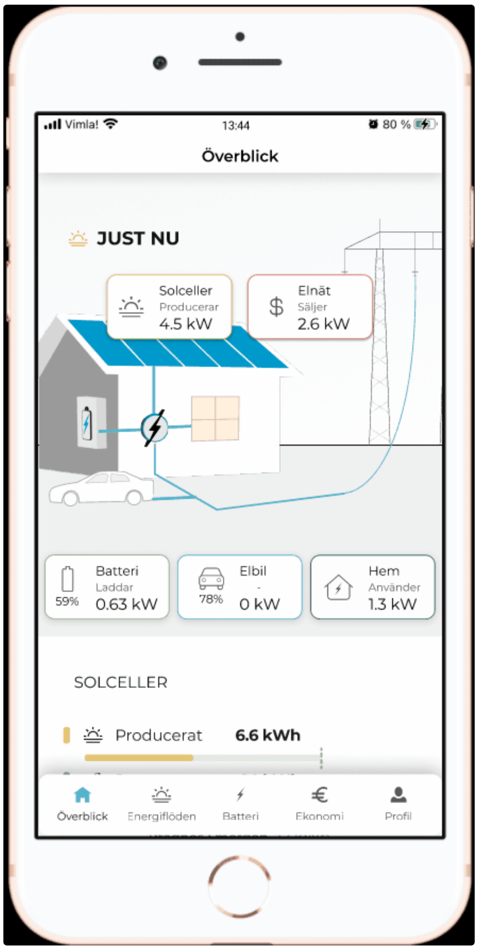
Preview mode: No answers will be saved.

Överblick just nu

Övrigt att tillägga kring sidan som visas?

Enter your answer

Go to next step



Preview mode: No answers will be saved.

Batteri

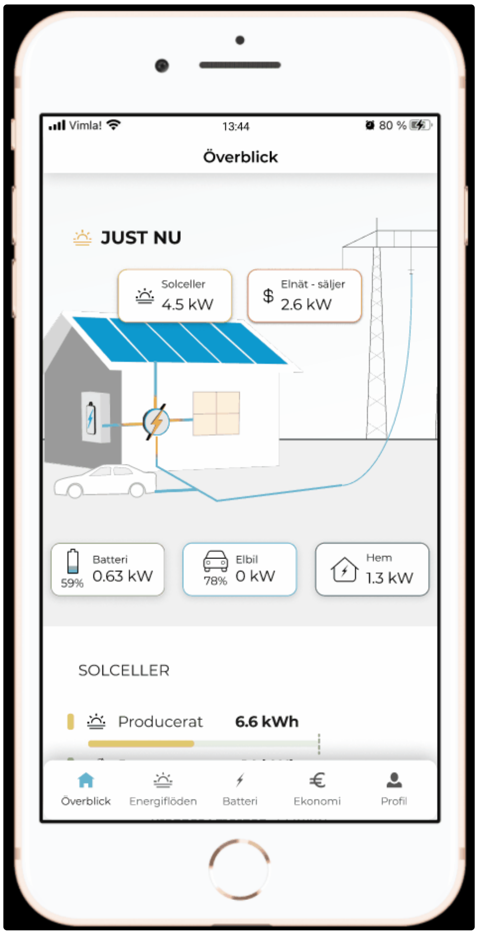
Denna funktion visar när ditt batteri senast stöttade elnätet.

Vad anser du om denna funktion?

1	2	3	4
5	6	7	

Ointressant — Intressant

Go to next step



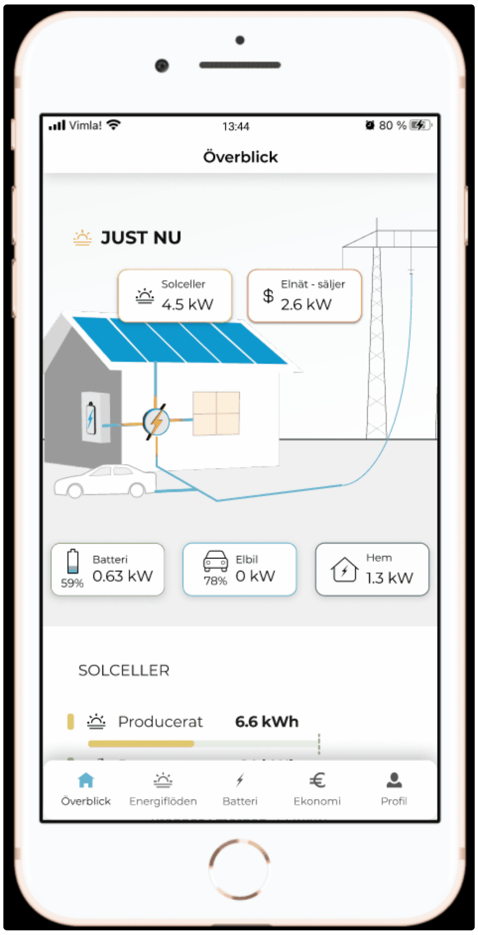
Preview mode: No answers will be saved.

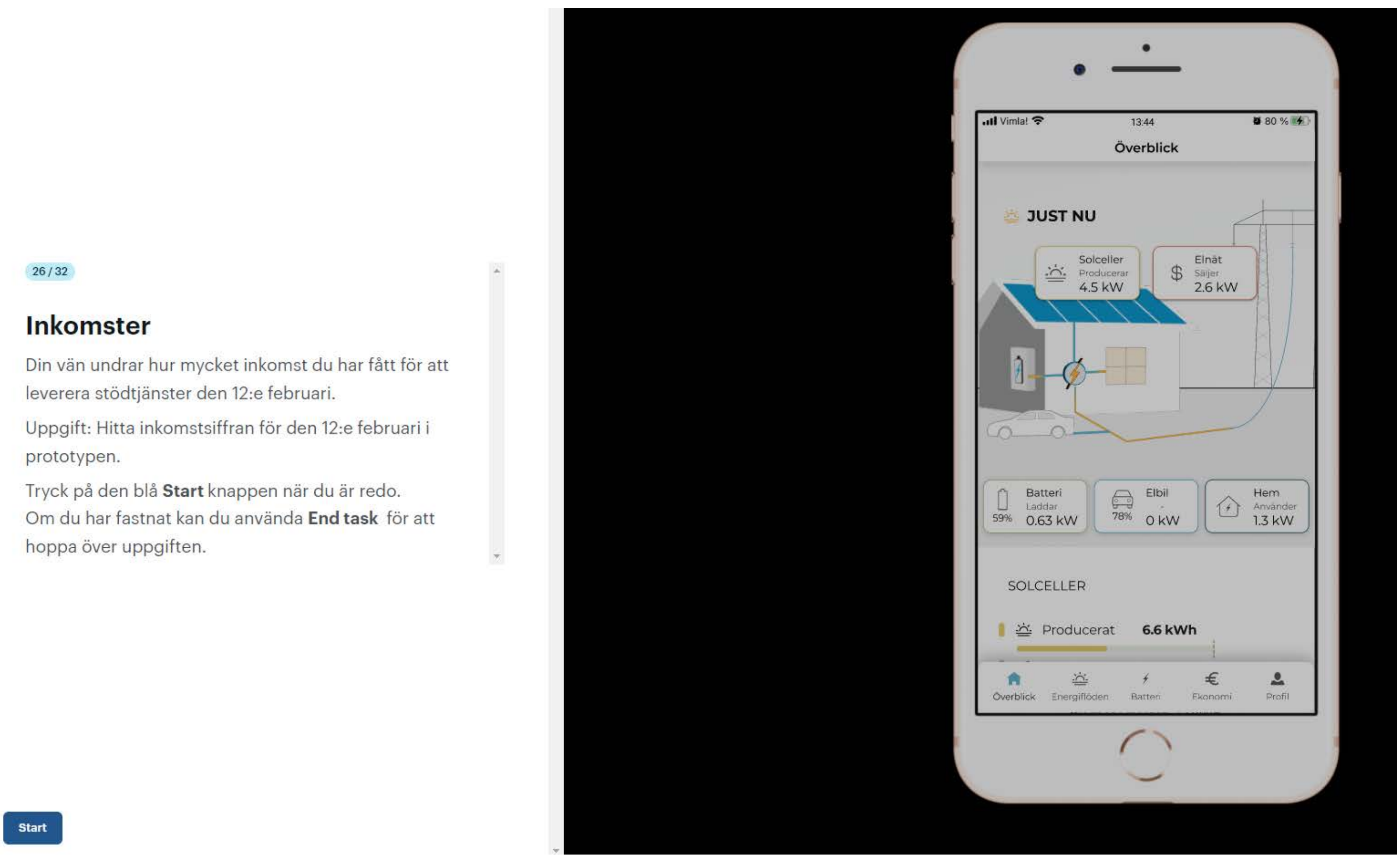
Batteri

Övrigt att tillägga kring sidan som visas?

Enter your answer

Go to next step




26 / 32
Inkomster
Din vän undrar hur mycket inkomst du har fått för att leverera stödtjänster den 12:e februari.
Uppgift: Hitta inkomstsiffran för den 12:e februari i prototypen.
Tryck på den blå **Start** knappen när du är redo.
Om du har fastnat kan du använda **End task** för att hoppa över uppgiften.
Start
Överblick
JUST NU
Solceller
Producerar
4.5 kW
Elnät
Säljer
2.6 kW
Batteri
Laddar
59%
0.63 kW
Elbil
78%
0 kW
Hem
Använder
1.3 kW
SOLCELLER
Producerat
6.6 kWh
Överblick
Energiflöden
Batteri
Ekonomi
Profil

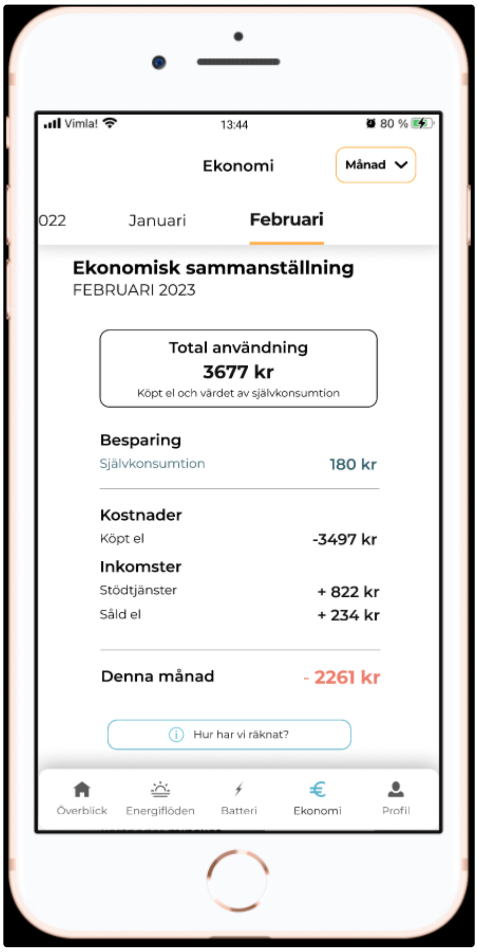
Preview mode: No answers will be saved.

Ekonomisk sammanställning

Vad är det ekonomiska resultatet av februari månad? Det vill säga, vad kostar dig månaden efter att du har betalt för köpt el och fått betalt för stödtjänster och såld el?

- 3497 kr
- Vet inte
- 3677 kr
- 2261 kr - 180 kr
- 2261 kr + 180 kr
- 2261 kr

Go to next step



Preview mode: No answers will be saved.

Återbetalningstid

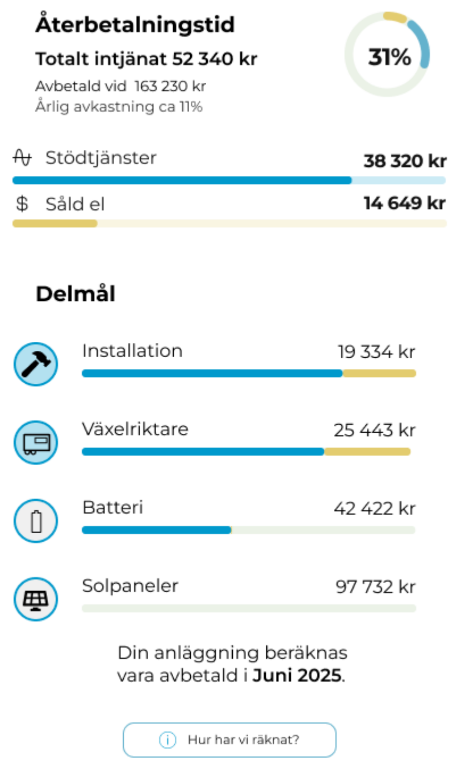
Vad tycker du om denna funktion?

1 2 3 4

5 6 7

Inte användbar — Mycket användbar

Go to next step



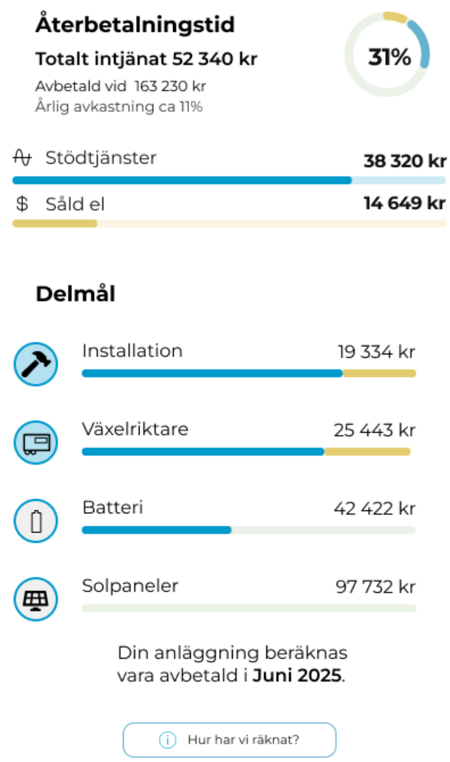
Preview mode: No answers will be saved.

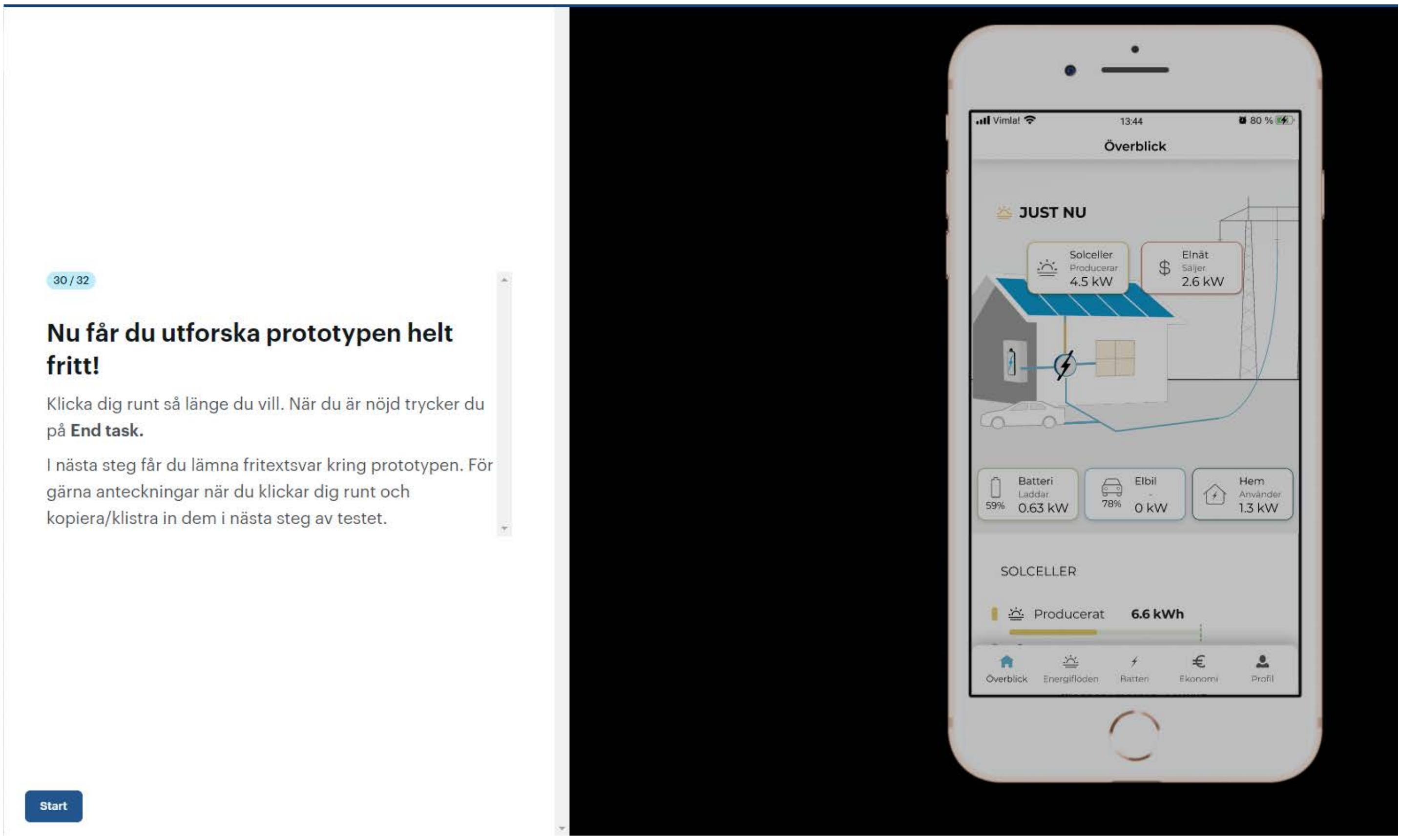
Återbetalningstid

Övrigt att tillägga om funktionen?

Enter your answer

Go to next step




30 / 32
Nu får du utforska prototypen helt fritt!
Klicka dig runt så länge du vill. När du är nöjd trycker du på **End task.**
I nästa steg får du lämna fritextsvar kring prototypen. För gärna anteckningar när du klickar dig runt och kopiera/klistra in dem i nästa steg av testet.
Start
13:44
Överblick
JUST NU
Solceller
Producerar
4.5 kW
Elnät
Säljer
2.6 kW
Batteri
Laddar
59%
0.63 kW
Elbil
78%
0 kW
Hem
Använder
1.3 kW
SOLCELLER
Producerat
6.6 kWh
Överblick
Energiflöden
Batteri
Ekonomi
Profil

Preview mode: No answers will be saved.

Här kan du fylla i ytterligare tankar efter att du har klickat dig runt i prototypen.

Fylla gärna på med dina tankar eller lämna fältet tomt om du vill.

Enter your answer

Go to next step

Preview mode: No answers will be saved.

Nu är testet klart!

Om du vill, så kan du fylla i din e-postadress så kanske vi kontaktar dig när vi har gjort ändringar i prototypen. Vi kommer inte att använda din e-post till något annat så som nyhetsbrev eller liknande. Den 10:e juni 2023 tas din e-postadress bort ur listan.

Email address

your@email.com

Finish

B.4 Unsupervised Test Result

Tester number	1	2	3	4	5	6	7	8
Könsidentitet	Man	Man	Man	Man	Man	Man	Man	Man
Hur hittade du hit?				Facebookgrupp CheckWatt Kunder	Facebookgrupp CheckWatt Kunder	Facebookgrupp CheckWatt Kunder	Fick länken i ett meddelande	Facebookgrupp CheckWatt Kunder
Har du solpaneler och batteri?	Jag har varken solpaneler eller batteri	Jag har varken solpaneler eller batteri	Både solpaneler och batteri	Både solpaneler och batteri	Både solpaneler och batteri	Jag har varken solpaneler eller batteri	Både solpaneler och batteri	Både solpaneler och batteri
Känner du till stödtjänstmarknaden?	Ja, litegrann	Ja, ganska bra	Ja, ganska bra	Ja, ganska bra	Ja, ganska bra	Ja, litegrann	Ja, litegrann	Ja, ganska bra
Är du ansluten till CheckWatts tjänster?	Nej	Nej, men jag har	Nej, men jag är i	Ja	Ja	Nej, men jag har	Ja	Ja
Hur ofta kollar du i appar relaterade till energi?			En gång i veckan	Flera gånger per	Flera gånger per	Flera gånger per	Flera gånger per	Flera gånger per
Scenario								
Solel igår - Hit goal	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Solel igår - Misclick	0%	0%	0%	0%	0%	0%	0%	0%
Solel igår - Duration	0.00.07	0.00.28	0.00.40	0.00.09	0.00.56	0.00.37	0.00.13	0.00.23
Solelsproduktion i morse - Hit goal	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Solelsproduktion i morse - Misclick	18%	0%	0%	0%	0%	0%	0%	0%
Solelsproduktion i morse - Duration	0.01.10	0.00.36	0.00.05	0.00.31	0.00.03	0.00.08	0.00.14	0.00.14
Solceller	7% bättre än snitt so far, eller jämfört med igår	7% mer än prognosen.	Produktion över prognosen.	svårt att förstå, 7% mer än prognos men det stämmer ju inte	Hur stor del av produktionen som säljs	7% mer än förväntat produceras 0800 (dvs högre effekt)	Min anläggning har producerat 7% mer än prognosen vid den tidpunkten	7% mer än prognos vid det klockslaget
Prognos solelsproduktion (out of 7)	6	2	5	3	5	6	6	4
Prognos solelsproduktion	Känns användbart. Om jag t ex vill koda när jag vill att min pool ska värmas :D	Vad bygger prognosen på? Det behöver man veta för att kunna förstå varför utfallet blir annorlunda. Tänker även att prognoser är mer intressanta på länbgre tidsperioder än en enskild timme, eller dag.	Inte just nu.	inte viktig, man jmf per månad efter offert eller så får man skapa prognos baserat på optimalt söder men det är för många parametrar, taklutning antal celler osv	Är data baserad på väderleksrapport?	Nej	Tar prognosen hänsyn till takvinkel och i vilket väderstreck panelerna är monterade ?	
Elanvändning	Solceller	Solceller	Solceller	Solceller	Solceller	Solceller	Solceller	Vet inte
Elanvändning	Inte helt klart hur jag kunde förstå varifrån förbrukad el kom. Men eftersom det såldes el antog jag att jag hade mer än jag gjorde av med. Så min förbrukade el borde kommit från mina egna solceller?	Staplarna matchar inte kurvan. Varför inte ha adderad kurva istället?	Det visas var solproduktionen tar vägen, men kan jag också se min fastighets konsumtion under "Energiflöden"?	no				Ni frågade vad strömmen kommer från! Inte vad den använts till. Skifta ordning på Totalt och Självkonsumtion
Växla mellan kWh och kr	5	7	7	5	7	6	7	2

Tester number	9	10	11	12	13	14	15	16
Könsidentitet	Man	Man	Man	Kvinna	Kvinna	Kvinna	Kvinna	Kvinna
Hur hittade du hit?	Fick länken i ett meddelande	Fick länken av en kompis	Fick länken i ett meddelande	Fick länken i ett meddelande	Fick länken av en kompis	Fick länken i ett meddelande	Fick länken i ett meddelande	Fick länken av en kompis
Har du solpaneler och batteri?	Både solpaneler och batteri	Både solpaneler och batteri	Både solpaneler och batteri	Jag har varken solpaneler eller batteri	Bara solpaneler	Bara solpaneler	Jag har varken solpaneler eller batteri	Jag har varken solpaneler eller batteri
Känner du till stödtjänstmarknaden?	Ja, ganska bra	Ja, ganska bra	Ja, ganska bra	Nej	Nej	Nej	Nej	Nej
Är du ansluten till CheckWatts tjänster?	Ja	Ja	Ja	Nej	Nej	Nej	Nej	Nej
Hur ofta kollar du i appar relaterade till energi?	Flera gånger per	Flera gånger per	Flera gånger per	Aldrig	En gång per dag	En gång per dag	Aldrig	En gång i månaden
Scenario								
Solel igår - Hit goal		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Solel igår - Misclick	0%	33%	0%	11%	0%	0%	33%	25%
Solel igår - Duration		0.00.29	0.00.03		0.00.27	00.00.12	00.00.41	00.00.30
Solelsproduktion i morse - Hit goal		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Solelsproduktion i morse - Misclick	0%	0%	0%	0%	0%	0%	0%	0%
Solelsproduktion i morse - Duration		0.00.33	0.00.04	0.00.21	0.00.11	00.00.05	00.00.22	00.00.09
Solceller	7% mer än prognos	7% över prognos	7% över min installerade effekt	producerat 7% mer än prognos	Det producerades 7% högre energi än vad prognosen sa.	Att anläggningen producerat 7% mer än vad prognosen angett mellan kl 12:30-16:00 (ca)	att de producerat 7% mer än prognosen visade	att jag producerat mer el än jag använder vid den tiden
Prognos solelsproduktion (out of 7)	4	5	6	6	6	4	7	3
Prognos solelsproduktion			har den med det lokala vädret eller basserad på historik eller båda?		Vad baseras prognosen på? Historik, vädret? Något annat?		Nej, tycker det är tydligt och bra med både den 100%-iga linjen tillsammans med tabellen, tydligt och snyggt!	Jag är osäker på det ska ge mig att veta hur mycket jag producerat i förhållade till en påhittad siffra. Möjligtvis att jag kanske försöker anpassa min elanvändning efter hur mycket som förväntas produceras den dagen. T.ex. om det är en molning dag och prognosen är låg kanske jag väntar med att köra tvättmaskin och diskmaskin till en solig dag.
Elanvändning	Solceller	Elnätet	Solceller	Solceller|Batteri	Solceller	Solceller	Solceller	Solceller
Elanvändning			skulle vilja zooma in graf och kolla med större upplösning, samt skulle vilja se på undersida graf som tar från nätet				tycker det är tydligt, speciellt med texten ovanför tabellen med hur mycket man själv använt i jämförelse med hur mycket man producerat. tydligt att man producerar mer än det går år och därför kan sälja överskottet	
Växla mellan kWh och kr	6	5	7	7	3	4	7	7

Växla mellan kWh och kr	Nej	Hur sätts priset per kWh?	Måste vara försiktig i vad man säger att solelen "kostar" då den anses vara gratis, men ja den kunde ha sålds om den inte konsumerades och då är det en kostnad, bra att ni skiljer på "Att betala" och "Totalt"	ja om spotpriset multipliceras med producerad kraft			Är det spotpris endast eller finns det något val för att visa den faktiska kostnaden för såld/köpt el? Dvs inklusive skatt, moms mm.	OM det är VERKLIG summa är det användbart men EJ om man sätter ett fast pris i en inställning.			att man skulle kunna lägga på en fast faktor på spotpris, samt att dom med fastpris avtal på el man köper borde kunna sätta fastpris		Man måste kunna ställa in ett fastpris för inköp av el, samtidigt som man kör spotpris för försäljning av överskottet av el. Vill man dessutom räkna på hur investeringen betalar av sig vill man också räkna på hur mycket man sparat genom att använda egenproducerad solel.		nej, det är väl bra att man kan växla beroende på vad man är intresserad av, kWh kanske inte säger så mycket för all	Jag tycker att det är viktigt att se vad elen kostar. Det gör att jag är mer sparsam med att använda den
Överblick just nu	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet laddas ur med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Batteriet är på uppladdning med 0.63 kW|Du använder 1.3 kW solel i hemmet	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW|Du säljer 2.6 kW till elnätet|Du använder 1.3 kW solel i hemmet|Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW, Du säljer 2.6 kW till elnätet, Du använder 1.3 kW solel i hemmet, Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW, Du säljer 2.6 kW till elnätet, Du köper 1.3 kW från elnätet till hemmet, Batteriet är på uppladdning med 0.63 kW	Dina solceller producerar 4.5 kW, Du säljer 2.6 kW till elnätet, Du använder 1.3 kW solel i hemmet, Batteriet är på uppladdning med 0.63 kW
Överblick just nu	5	4	6	4	7	7	7	4	6	6	5	3	7	5	5	5
Överblick just nu 2	Bra överblick. Inte helt solklart vad dom olika grejerna är (för mig som nybörjare), men det vill man i så fall läsa på en info-/hjälpsida. Hade inte önskat mer förklarande text på denna sida.	Grafiken på huset är otydlig, för liten.	Precis som ni har gjort på "Elnät" att ni lagt till "-säljer" så behövs även detta för Batteri och Elbil, att ni lägger till "Laddar" eller "Laddar ur" typ för att förtydliga vad som är positivt och negativa energiflöden.	no				Möjlighet i inställningar att ta bort Elbil om man inte har laddare.			kolla på sungroows app. dom har även en cirkel runt funktionerna och ned gör det väldligt tydligt med hur energin flödar	Inte helt tydligt vad om batteriet laddas eller används			Tycker det är tydligt, förutom Hem-delen, hur mycket man använder, man kanske bara är jag som har svårt att förstå hela grejen med att köpa och sälja och elnät och grejer. men förstår att jag just nu använder 1.3, inte laddar min bil för tillfället men laddar batteriet. Men var det man använder kommer från, om det är solceller eller från elnätet förstår jag inte helt	Jag förstår inte riktigt vilket tidsspan som menas. Det känns som att det är just nu. "Batteriet laddas och är 59% fullt" känns rimligt, men produceras 4,5 kW per sekund? timme? Eller är det "just så säljs 2.6 kW per varje 4.5 producerad kW"?
Batteri (out of 7)	6	7	7	5	7	6	7	5	4	7	7	7	4	5	4	1

Batteri 1	Ah, nu ser jag att tiden för dippen i laddnivå är samma som tiden för min insats. Inte helt solklart först att dom hängde samman.	Animeringen känner jag inte behövs.	Dagens insatser kan bli många på en dag, men mycket intressant för annars kan det se ut som att den inte gjort någonting alls.	det kunde vara intressant hur batteriet utnytjas dvs vad stödtjänsten tar i effekt från mig eller ger mig. Upp och ner kwh per månad tex				Skifta plats så Dagens insatser är över och den man väljer visas under. Då blir det också tydligare varför det är ett streck i grafen där man valt.			jag skulle vilja kunna ställa min uppladdning på mitt batteri mellan 50-70% på detta sättet kan jag själv vara med att ladda 20% när det 'r billigt och använda 20% när det r som dyrast på dygnet		Kan inte så mycket om batterier då jag inte har det själv.		kanske är intressant för vissa, men förstår inte gelt illustrationen eller vad det betyder	Det känns som en nördig funktion som inte är så intressant för mig
Inkomster - Hit goal	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes		No		Yes	Yes	Yes	Yes	Yes
Inkomster - Misclick	0%	0%	33.33%	15.38%	50.00%	75.00%	0%	0%	0%	37.93%	0%	0%	0%	66.7%	0%	50%
Inkomster - Duration	0.00.08	0.00.30	0.00.12	0.01.00	0.00.05	0.00.14	0.01.34	0.00.10		0.01.32		0.00.11	0.00.10	0.00.16	00.00.39	00.00.13
Ekonomisk sammanställning	2261,00 kr	2261,00 kr	2261,00 kr	2261 kr + 180 kr	2261 kr + 180 kr	2261,00 kr	2261,00 kr	2261,00 kr	2261,00 kr	2261,00 kr	2261,00 kr	2261,00 kr	2261,00 kr	2261,00 kr	2261,00 kr	2261,00 kr
Återbetalningstid (out of 7)	7	5	5	4	7	3	7	2	4	6	4	6	7	7	7	6
Återbetalningstid 1	Nej	Nice to have.	Även självkonsumerad el bör ingå i de besparingar detta lett till. Sedan bör "(FCR + EA)" tas bort. EA är spotprisarbitrage och ingår i såld el delvis.	ni skannar för fort, hinner inte med att se	Superbra funktion. Bäst hitintills	Jag gör inte detta i denna typ av app	Den funktionen har jag aldrig sett i någon app tidigare, roligt och intressant att se.	Snygg men inte såå viktig. Visst, men inget jag kommer kika ofta på			ved ger det för mervärde? Jag har redan köpt dem och lite matematik kan jag. Behöver inte varje dag kolla i appen på detta. Detta gör man först efter några år, när det börjar närma sig	Varför ger inte solpanelerna något? Inkludera när anläggningen installerades.	Delmål känns inte så viktigt. Jag vet också bara vad totalsumman för installationen var, inte hur mycket varje del kostade.		jättebra med en total sammanställning!	Kul! Det är givande att se att (/om) investeringen med solceller lönar sig. Kul att räkna ner!

C

Appendix C: Moscow Analysis

	Will not have	Could have	Should have	Must have	Must have main page (importance)
Batteri	1	1	1	1	
Batterinamn/effekt			1		
Batteri-status	1	1	1	1	
Laddnivå			1		
Laddar i eller ur			1		
State of health		1			
Laddcykler		1			
Temperatur	1				
Värmare igång/ej		1			
Senaste testresultat - “it works”	1				
Stödtjänst				1	4
Typ av stödtjänst				1	4
Antal aktiveringar			1		
Senaste aktivering/dagens aktiveringar				1	5
toppeffekt/hur lång tid		1			
Historiska inställningar			1		
Schemalägga laddning av batteri (billig el)	1				
Vad är billig el? En cykel per dag / per vecka? Autor	1				
FCR	1	1	1	1	
Visualisera currently i relation till elnät				1	
Antal batterier (Antal hem)				1	
Sammanlagd effekt (teoretisk toppeffekt)				1	
Exempelvis motsvarar 1 kärnkraftverk		1			
Event:	1	1	1	1	
Aktivitet för batteriet			1		
Urladdning med 7.2kW i 20 sek			1		
Klockslag			1		
Frekvensförändring		1			
Aktivitet för hela currently				1	
System	1	1	1	1	
Kommunikation	1				
CM10 -> Internet	1				
CM10 -> EIB	1				
CM10 -> Växelriktare	1				
CM10 -> Smartmätare	1				
CM10 -> Batteri	1				
CM10 -> Solpaneler?	1				
Solceller	1	1	1	1	
Status		1			
Produktion - just nu / idag / historisk			1		
Självkonsumption - just nu / idag / historisk			1		
Konsumption - just nu / idag / historisk			1		
Prognos / virtual irradiance				1	3
Förbrukning	1	1	1	1	
Självkonsumption - just nu / idag / historisk			1		
Konsumption - just nu / idag / historisk			1		
(Last per fas)		1			
Priser	1	1	1	1	
Spotpris				1	4
15minuters upplösning?	1				
Effekttariff		1			
Ekonomi	1	1	1	1	
Förtjänst	1	1	1	1	

	Will not have	Could have	Should have	Must have	Must have main page (importance)
Stödtjänster				1	5
FCR				1	5
EA				1	5
Solceller			1		
Genomsnittlig förtjänst per dag / månad / år		1			
Besparingar	1	1	1	1	
Stödtjänster	1				
(PS)		1			
Solceller			1		
Självkonsumption	1	1	1	1	
Solel		1			
Batteri (laddat billigt) - om 30% av batteri kan användas/EA		1			
Kostnader	1	1	1	1	
Inköpt el från elnät			1		
Se mängd energi använd i stödtjänsterna			1		
Se kostnad för energi i stödtjänsterna		1			
Investeringar	1	1	1	1	
Investeringskostnader för:					
Solceller		1			
Batteri			1		
Växelriktare			1		
CM10			1		
"Sparmål"			1		
Avkastning		1			
Integration	1	1	1	1	
Elbilsladdare	1	1	1	1	
Förbrukning denna månad		1			
Kostnad för ovan		1			
Genomsnitt pris för laddning kr/kWh		1			
Laddnivå		1			
Status (laddar eller ej)		1			
Laddning klar kl		1			
Kostnad för nuvarande/kommande laddsession		1			
Kostnad för förra laddsessionen		1			
Förslag på bra timmar att ladda		1			
Värmepump		1			
Temperatur inomhus just nu - olika rum		1			
Tänkt temperatur - 20 grader		1			
elprisstyrning		1			
Förbrukning		1			
Semesterläge		1			
FCR		1			
Samma info som för batteri?		1			
Hålbarhet	1	1	1	1	
Sparmål CO2			1		
Kommunicera värdet av stödtjänster				1	
Sammanlagd effekt av alla solcellsanläggningar anslutna. Hur mycket är det jämfört med vindkraftverk?		1			
Jämförelse	1	1	1	1	
Jämförelse med andras produktion/förbrukning/stöttning av elnät		1			

D

Appendix D: Personas

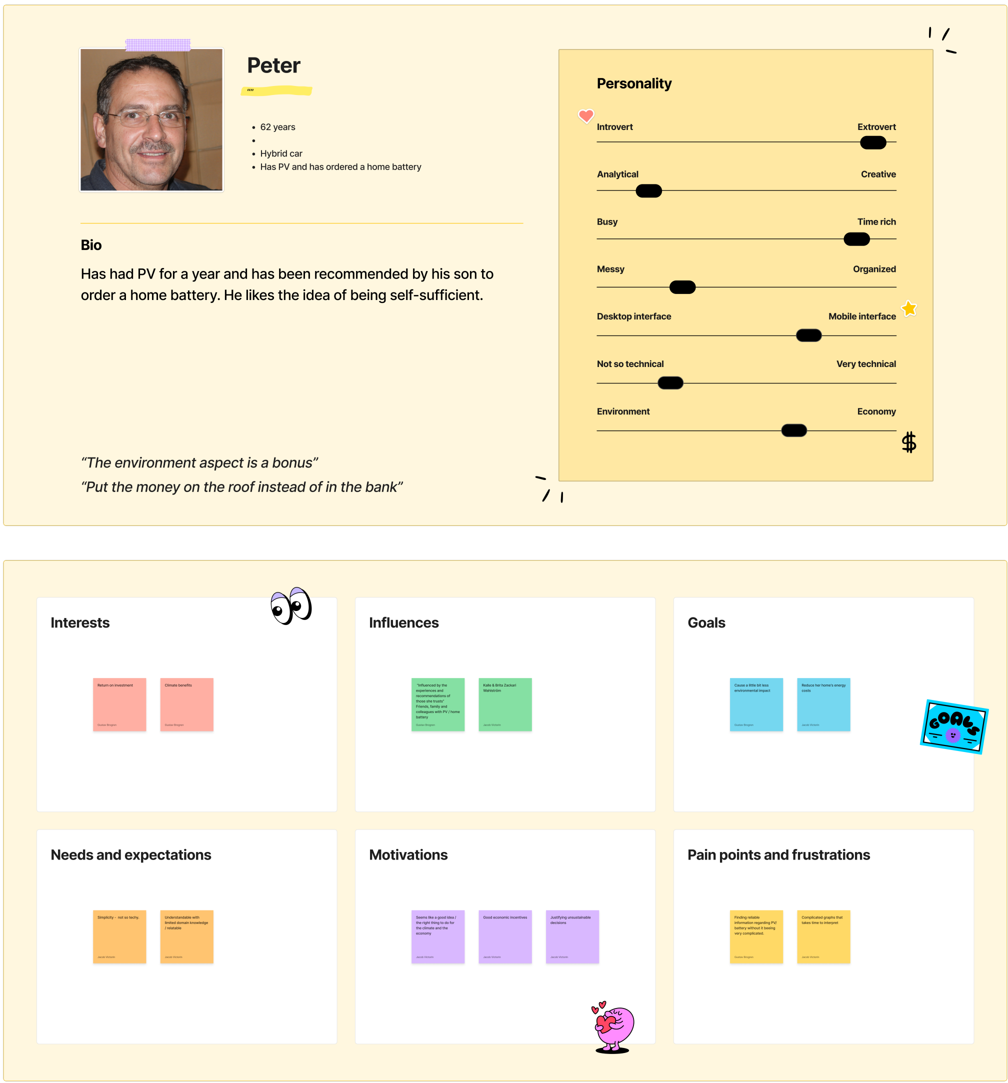


Figure D.1: Persona

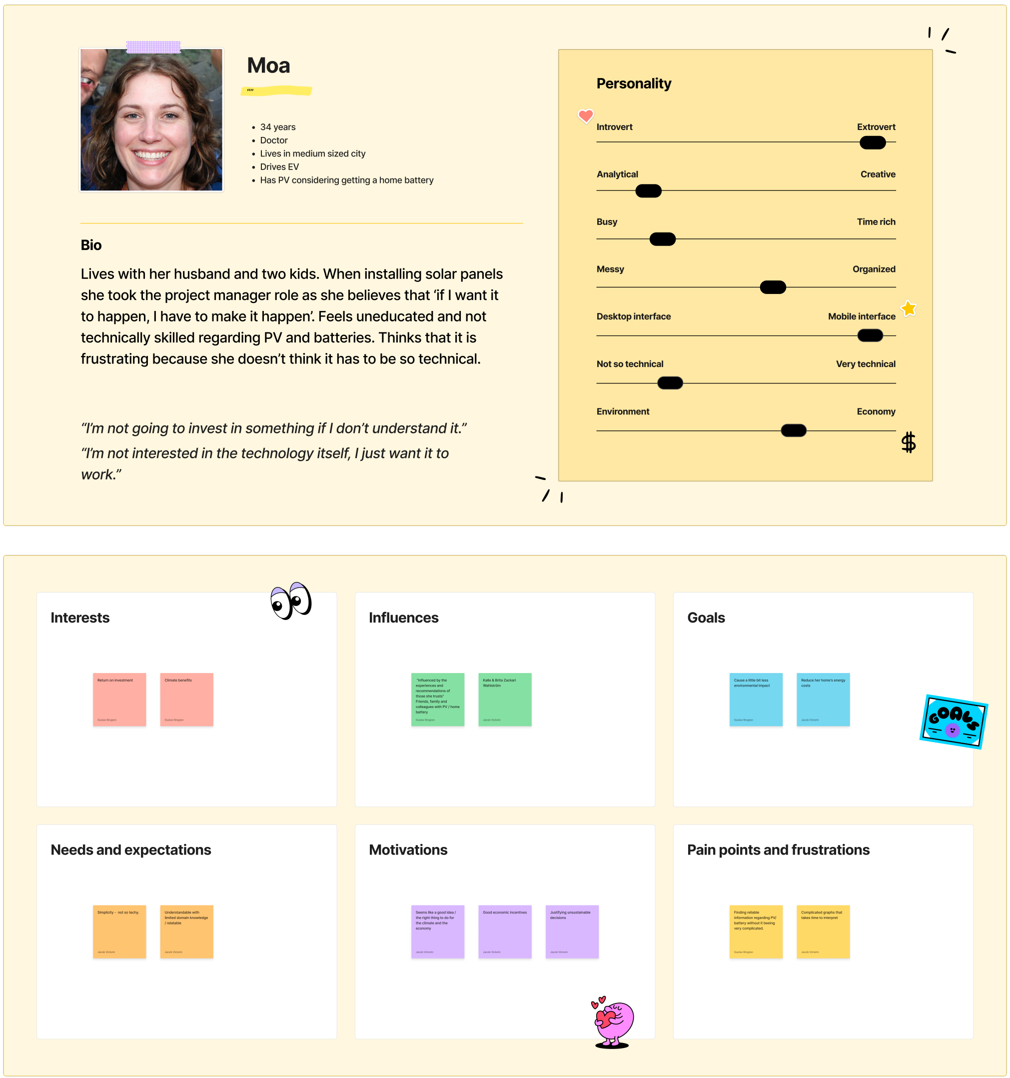


Figure D.2: Persona

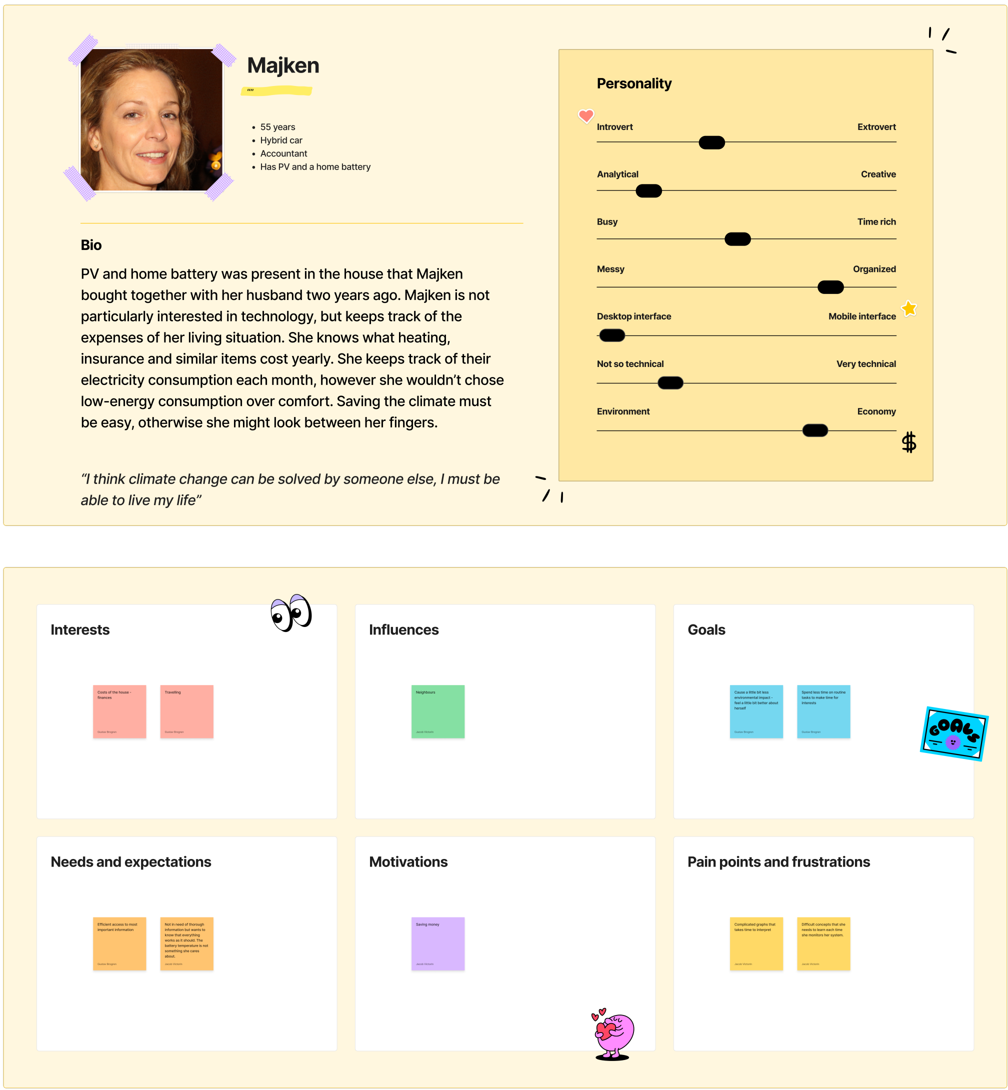


Figure D.3: Persona