Visualization of electricity consumption and solar panel production for house owners

Filip Hammarberg
id12fhg@cs.umu.se
June 11, 2018

Abstract

In only two hours, the earth receives sunlight containing the amount of energy equivalent to one year’s electricity consumption of the entire population. Yet only 0.09 percent of the electricity production in Sweden 2016 came from solar energy. To increase that amount, the energy and communications company Umeå Energi offers solar panels to their customers. While doing that, they have identified a desire for their customers to monitor their electricity consumption and production at the same place – something that the service lacks today.

This thesis investigates the actual needs behind why the solar customers want to know the electricity consumption and production information, in what contexts it will be accessed, and how that can be visualized to meet their needs.

Starting with a literature study to understand the area, the work continues by meeting and interviewing customers to collect insights. These insights are then used as a foundation when creating and testing prototypes repeatedly together with the customers.

It was found that being self-sufficient is one of the most important reasons for their solar panel customers for producing their own electricity. The prototypes that were created aimed to address that self-sufficiency need, together with visual representations of their electricity production and consumption – both historically as well as with live data.

Master Thesis.
Supervisor: Thomas Mejtoft.
# Contents

1 Introduction ............................................. 3
   1.1 Objective ........................................... 3
      1.1.1 Purpose ....................................... 3
      1.1.2 Achievement ..................................... 4
      1.1.3 Limitations ..................................... 4
   1.2 Terminology ......................................... 5
   1.3 About Daresay ....................................... 5

2 Theory .................................................. 6
   2.1 How solar panels work ............................... 6
   2.2 Getting customer insights ......................... 7
      2.2.1 The interview ................................... 7
      2.2.2 Putting learnings to use ....................... 9
      2.2.3 Finding themes in learnings .................... 9
   2.3 Things to consider ................................ 10
      2.3.1 How can one relate to electricity consumption’? 10
      2.3.2 Resolution ..................................... 11
      2.3.3 Amount of information .......................... 12
      2.3.4 Color blindness ................................ 12
      2.3.5 Target group .................................... 12
      2.3.6 Survivorship bias ............................... 14
   2.4 Visualizing information ............................. 14
      2.4.1 Design approaches for energy visualization . 14
      2.4.2 Feedback system ................................ 15
      2.4.3 Different types of graphs ........................ 16
   2.5 How others have done .............................. 21

3 Method .................................................. 23
   3.1 Literature study .................................. 23
   3.2 Design method ..................................... 23
      3.2.1 A. Investigate needs, context, behavioural groups. 24
      3.2.2 B. Define behavioural groups .................... 26
      3.2.3 C. Define needs, context, measuring unit, resolution, time window. 26
      3.2.4 D. Involve Umeå Energi ......................... 26
      3.2.5 E. Investigate how the data can be visualized .... 26
      3.2.6 F. Create prototypes based on insights from E. 27
      3.2.7 G. Evaluate prototypes together with users .......... 27
      3.2.8 H. Evaluate the result ......................... 27

4 Results .................................................. 28
   4.1 Insights from Umeå Energi’s pre-study ............ 28
   4.2 Interviews and insights ............................ 29
4.2.1 Behavioural groups ........................................ 31
4.2.2 Measuring unit ............................................. 36
4.2.3 Resolution .................................................. 37
4.2.4 Time window ............................................... 37
4.3 Touching basis with Umeå Energi .............................. 38
4.4 Visualizing consumption and production ...................... 38
4.5 Prototypes, iteration 1 .......................................... 40
4.6 Insights from prototypes, iteration 1 ......................... 43
4.7 Prototypes, iteration 2 .......................................... 43
4.8 Insights from prototypes, iteration 2 ......................... 45
4.9 Prototypes, iteration 3 .......................................... 45
4.10 Insights from prototypes, iteration 3 ......................... 47
4.11 Prototypes, iteration 4 .......................................... 48

5 Discussion ........................................................ 50
5.1 Method ......................................................... 50
5.1.1 Literature study ............................................. 50
5.1.2 The service design methodology ......................... 50
5.2 The result ..................................................... 50
5.3 Conclusions ................................................... 52
5.4 Future Work .................................................. 53
5.4.1 Investigation of early majority ....................... 53
5.4.2 Prediction of solar production based on weather forecast 53
5.4.3 Prediction of solar production and/or electricity consumption by 53
data analysis .................................................. 53
5.4.4 Detection of snow on solar panels by data analysis ...... 54
1 Introduction

In two hours, the earth receives the amount of energy equivalent to one year’s electricity consumption of the entire population [1]. Yet only 0.09 percent of the electricity production in Sweden 2016 came from solar energy [2]. Solar panels have been used in Sweden for converting energy from sunlight into electricity since the 1970’s [3]. The most common application was initially for independent systems not connected to the electrical grid, such as boats, cabins and caravans. Today the applicable area has broadened and the interest for connecting solar panels to the electrical grid has increased firmly. The technology has evolved and become less expensive, and there are options for financial support to gain from the Swedish government [3].

There are several services and products that offer the possibility to monitor electricity production, live and with historical view, if you are in possession of solar panels [4, 5]. Similarly, there are options for monitoring electricity consumption [6, 7, 8]. It seems however not to be a way of having both of which presented together without the need of using two different services or products. Being able to easily see to what extent one is supplying the household’s electricity consumption with the solar panel production may seem like a natural ability, but in the work of this thesis no such service has been found. This gap is something that Umeå Energi [9] has identified, and is working for to fill.

Umeå Energi is a Swedish energy and communications company that provides a grid for electricity and broadband. In 2016 they expanded their offer, enabling their customers who are house owners to buy or rent solar panels. Among those customers, Umeå Energi has identified a need of being able to do what is currently missing on the market – monitoring and comparing both their electricity consumption and production at the same place. The customers are lacking the possibility to tell others, or get feedback themselves, about their choice to produce their own electricity.

This thesis aims to investigate the actual needs behind why the solar customers want to know the electricity consumption and production information, in what contexts that will be accessed, and how that can be visualized to meet their needs.

1.1 Objective

This section describes the work in terms of intentions and limitations.

1.1.1 Purpose

The purpose of this study is to find the most suitable way for how, where and when the customers can get their information about solar panel production and household electricity consumption presented together. Hopefully are the findings possible to apply to other areas with a similar in-and-out flow of energy, information or such.
1.1.2 Achievement

The achievement is to find the customer needs for Umeå Energi’s current solar panel customers, and create a first prototype that meets their needs regarding their solar panel production and electricity consumption. The insights and the prototype will be used as a foundation when continuing on the work for Umeå Energi after this thesis.

1.1.3 Limitations

There are few limitations within the implementation of the work; it is conducted with an experimental and exploring approach. But there are circumstances linked to the carrying through of the thesis that are limiting, these are described below.

- **Target group** – The target group, Umeå Energi’s current solar panel customers, may not be representative to the users joining the product cycle further on. See section 2.3.5 for further reasoning regarding this.

- **Customer sample** – The amount of current customers provided by Umeå Energi for contacting regarding interviews and contact during the prototyping is limited. There is a chance that conclusions drawn from this sample not is applicable to the target group as a whole.

- **Missing customers** – The potential customers that for some reason has not signed up for solar panels given the opportunity are not looked into. See section 2.3.6 for further reasoning regarding this.

- **Time frame** – Time, especially man-hours, is one of the biggest limitations in this work. Even if there was a bigger customer sample it might not be enough time to deal with everyone appropriately. More iterations in all contact with users – interviewing and prototyping – could be done if there was more time available, probably resulting in better results.

- **Visual representations** – The work is, due to the time limitation, restricted towards visual representations and does not take any other senses into consideration. Nor does it compensate for people with vision problems, color blindness and such.

1.2 Terminology

Description of often used terms below.

- **User/customer** – Customer to Umeå Energi renting solar panels.

- **Production** – The process of producing electricity by the solar panels connected to the house.

- **Consumption** – The household consumption of electricity from the electric grid.
• **Surplus** – The electricity produced from the solar panels that exceed the current consumption. It is being sold to Umeå Energi (this can in the future be stored in batteries for later usage).

• **kWh** – Kilowatt-hour; one thousand watt-hours. A unit for measuring energy consumption. Example: A 6 watt light bulb active for one hour will consume $6W \times 1h = 6Wh = 0.006kWh$.

• **Inverter** – The solar panels produce electricity as direct current, which has to be converted into alternating current for being able to use in the household. This conversion is made in the inverter, which is installed in the customers house.

• **Current app** – The supplier of the inverter offers an app to smartphones where it is possible to see the production visualized.

• **SEK** – The currency used in Sweden.

1.3 **About Daresay**

This work has been performed at Daresay at their office in Umeå, Sweden, with support from them as well as from people at their office in Stockholm.

Daresay is a digital agency that creates customer experiences. Together with their clients, they help them become a successful digitally-driven company. They have been working together with clients as Ikea, Telia, Arbetsförmedlingen and Microsoft. [10]
2 Theory

This section builds a theoretical framework based on the findings in the literature study. It will be used as a foundation, referred to throughout the thesis. It is divided into five parts illustrated in Figure 1, and the Method chapter continues afterwards taking the findings in the Theory chapter into consideration.

![Theory outline](image)

**Figure 1 – Theory outline**

2.1 How solar panels work

The electricity produced by the solar panels gets consumed by the household at the same time and cannot be used at a later moment. That is if not the system has batteries
that can accumulate the electricity. Such batteries are not offered today by Umeå Energi with their solar panels. The solar production first goes through the inverter where it gets transformed from direct current to alternating current, before it gets consumed by the household or sent out to the electrical grid if exceeding the current consumption (surplus production). If there is surplus production, that electricity is then credited from the consumption in the next month’s bill, with some exchange (currently each kWh credits 0.35 SEK, which is lower than what a kWh is sold for from Umeå Energi). The customer is also dependent on the electrical grid to benefit from the solar panels – if the grid goes down for some reason, the solar panels does not power the household due to technical limitations (if not accumulated energy is stored in a battery that can be used). See Figure 2 for a simplified visual scheme.

Figure 2 – Basic functioning of solar panels

2.2 Getting customer insights

In order to start the design phase, a foundation of customer insights will be collected. This will be made by interviewing customers and analyzing the results.

2.2.1 The interview

Interviews are the essence of the initial phase in a human-centered design project. The goal is to get to the interviewees and hearing from them in their own words [11]. The design company IDEO [12] writes that one should, whenever possible, conduct the interviews in the interviewee’s own space – learning about a person’s mindset, behaviors
and lifestyle by conversing with him or her where they live or work can give more insight than if done at another place \[11\].

**Five advice when interviewing customers**

The service design company Transformator Design \[13\] has stated five advice when interviewing customers \[14\] which have been taken into consideration:

1. "**Wide framing of questions.** Avoid *yes or no*-questions and emotionally charged questions such as 'are you worried that...'. Try using questions that open up for telling."

2. "**‘Why, why, why..?’** Always try to reach deeper through asking the follow up question 'why?' several times."

3. "**Listen more than you talk.** Wait for expressions of needs, driving forces, behaviours and expectations. That often makes the interviewee to widen the answer and explain in more detail."

4. "**Trigger material.** When one has to understand more within a specific area, or wants to test an idea or hypothesis in an early stage – it is often giving to use some sort of trigger material. 'What does that look like?', 'How could that work?'. Trigger material is something that triggers a reflection and opens up for insights and ideas."

5. "**Empathy.** It is of great concern that the interviewee does not feel uncomfortable, pressed or dumb during the interview. It is more of a conversation than to get answers to a list of questions. A genuine will to understand his or her situation and needs is what shall carry the interview – not a search for the right answers or that he or her shall confirm that you are thinking the right thing."

**The five whys**

The design company IDEO \[12\] has written guidelines for conducting an interview, one of which regarding *The Five Whys* (also mentioned briefly in point \[2\] in Section \[2.2.4\]'s list). They mean that it is fantastic method for getting to the interviewee’s core beliefs and motivations. Their advice is to start with very broad questions and then ask *why* five times in order to get essential answers to difficult problems \[15\]. They state the steps for achieving this as:

1. "This one is pretty easy. Start by asking a pretty broad question about your Interview participant’s habits or behaviors then ask ‘why’ to their response five times in a row."

2. "Remember that you’re not asking a horizontal question, (ie 'Why else didn’t you get a good harvest this year?') you’re actually going for depth (ie 'Why weren’t you able to buy the fertilizer you needed?')."

3. "Write down what you hear, paying special attention to moments when it feels
like you’ve moved a level deeper into understanding why the person does what she
does."

4. "Keep in mind that you might not get to the core stuff until the fourth or fifth
‘Why.’"

**Body language**

IDEO means that the body language of the person conducting the interview plays a big
part in the process [16]. Keeping eye contact, smiling and nodding are non-verbal ways
of reinforcing what the interviewee is saying. They add that truly engaged listening can
be as important as the actual questions asked. The job when conducting an interview is
not to getting inserted into the conversation or coming with solutions – it is hearing and
recording strictly what the interviewee is telling.

### 2.2.2 Putting learnings to use

After the initial phase with interviewing the users, a big amount of data is gathered in
the shape of notes, photos, quotes and such. IDEO considers that teamwork is critical
to human-centered design, and have therefore created steps of putting the learnings to
use and sharing them within the work group [17]:

1. "Take turns Downloading. Start by getting rid of other distractions and sitting in
   a circle."

2. "When it’s your turn, put all key information you’re about to share on Post-its and
   use them as you describe who you met, what you saw, the facts you gathered, and
   your impressions of the experience."

3. "Cluster the Post-its together as you put them on the wall or on a board so that
   you have a record of your discussion."

4. "When it’s not your turn, pay close attention. Feel free to ask questions if something
   isn’t clear."

5. "This process is best done the day of an interview or after a day in the field.
   Download while your experiences and perceptions are fresh."

### 2.2.3 Finding themes in learnings

After learnings from interviews are compiled, themes and patterns can emerge. One
should be looking across all material for insights that show up repeatedly. Contemplate
over what is significant and try sorting out what the different themes mean. IDEO
recommends working with this using the following steps [18]:

1. "Gather your team around the Post-its. Move the most compelling, common, and
   inspiring quotes, stories, or ideas to a new board and sort them into categories."
2. "Look for patterns and relationships between your categories and move the Post-its around as you continue grouping. The goal is to identify key Themes and then to translate them into opportunities for design."

3. "Arrange and rearrange the Post-its, discuss, debate, and talk through what’s emerging. Don’t stop until everyone is satisfied that the clusters represent rich opportunities for design."

4. "Identifying these Themes will help you Create Frameworks and write Design Principles."

2.3 Things to consider

When creating the prototype, as well as when interviewing the customers, there are many things to consider. Below are important topics to have in mind when continuing the work of this thesis.

2.3.1 How can one relate to electricity consumption?

Speaking a language that the user understands is important. Stickdorn and Schneider [19] write an example in their book:

> If you remember an occasion when you tried to get technical assistance, like using a telephone helpline for example, it is common to have problems in how both parties involved understand each other. You and the hotline agent literally speak the same language, and yet it is often difficult to communicate because you exist in different realities. /.../ A user-centered approach offers a common language we can all speak; the service user’s language.

This is applicable to the entire process, however it is directly related to the choice of measuring unit for electricity production and consumption. The insights from Umeå Energi’s interviews give a picture that the kilowatt-hour (kWh) is an understandable unit. It is however important to relate to the fact that the current users probably fall under the categories innovators and early adopters as discussed in section 2.3.5. Their understanding to the kWh may differ to the customers who join the adoption cycle later on.

The Swedish energy company Alltid [20] has published results from a survey conducted by the analytics and research company Novus [21], regarding the knowledge about electricity consumption among Swedes. They concluded that, out of Swedish house owners, 46 percent does not know how much they are paying per kilowatt-hour [22]. This could imply that almost every other average Swedish house owner not would have an economical understanding of the consumption in terms of kilowatt-hours. According to Herrmann et al. [23], prior research has shown that people generally think of their energy consumption
in the matter of everyday activities and actions. For instance, people will think of taking a shower rather than using electricity for the purpose of heating water. Using metaphors might therefore be a way of bridging the gap of lacking understanding towards the kilowatt-hour.

2.3.2 Resolution

The average electricity consumption for a house in Sweden using direct electricity for heating is around 26 500 kWh per year [24]. An average house in Umeå, Sweden, where the main part of Umeå Energi’s solar panel customers are located could produce around 10 000 kWh per year using solar panels [25]. This is a rough estimation and varies due to circumstances such as roof size, surroundings, house direction and more. See Figure 3 for a comparison between this consumption and production.

![Figure 3 - Comparison between consumption and production in an average house](image)

This average amount of electricity consumption can further be divided into three main parts; hot water, household electricity and heating. The part household electricity contains all appliances in the house, such as lighting, TV, vacuum cleaner, etc. See Figure 4 for the same comparison as above, but with the consumption divided into the three parts mentioned.

![Figure 4 - Resolution 1](image)

This sectioning of consumption provides distinction within the consumed electricity and can be a tool for a different tasks. It could be to see if the solar panel production can cover a specific consumption section, or trying to cut down on another one in order to do so.

The section household electricity is subject to further division, tracking individual floors, rooms or even specific appliances. Depending on what the customer is aiming for with his
or her solar panel investment, the preferred resolution of the electricity consumption may vary. It will also matter how many divisions there are, since too many might demand too big cognitive effort by the user.

### 2.3.3 Amount of information

People can hold around four pieces of visual information in their short-term memory at a given moment. Nussbaumer Knaflic [26] means that we because of this want to limit the cognitive burden on the audience of going back and forth between multiple parts of a diagram. Trying to find the key elements that are of interest for the customers is therefore of great interest, so that there are as few pieces of visual information as possible.

### 2.3.4 Color blindness

Around 8% of men and 0.5% of women are color blind [26]. A common situation where color blind people have trouble distinguishing between colors is comparing shades of red with shades of green. Having this in mind when making visual design containing diagrams or other parts is essential for not losing readability. This is however not taken into consideration in the prototypes, as mentioned with the limitations in section [1.1.3].

### 2.3.5 Target group

Together with Umeå Energi, the target group has been defined as their current customers who are renting solar panels. This is a limitation in the sense that they might not be representative for the bigger mass of customers joining the product life cycle further on. When it comes to the technology adoption life cycle, Moore [27] clusters the users into five psychographic groups in the book *Crossing the Chasm*:

1. **Innovators** – People who pursue new technology products aggressively, and occasionally finds it before they have hit the market completely. Technology has a central role in their life.

2. **Early Adopters** – They also join new products life cycles in an early stage, but they differ from innovators in the sense that they are not technologists. They have the ability to imagine, understand and appreciate gains from a new technology, and can relate these to their own interests

3. **Early Majority** – Much like the early adopters, they have ability to relate to technology. But they are more driven on practicality than they are. They want to wait until they feel assured that the product will not fail, preferably with established references. This is the key segment to win for gaining substantial profit.
4. **Late Majority** – The members of this segment is much alike the early majority, but they waits even longer before investing in new products, they first want it to be an well-established standard.

5. **Laggards** – These people only buy new technology when they *must*. Perhaps it is deeply buried into another product, for instance a chip inside a digital camera that the user does not notice is changed.

![Figure 5 – Product Life Cycle](image1)

![Figure 6 – The Chasm](image2)

Figure 5 illustrates the product life cycle with time on the $x$-axis and customers on the $y$-axis. Figure 6 is the same figure, but with gaps between the different psychographic groups. The gaps symbolize the dissociation between the groups surrounding each gap. That means the difficulty each group will have in accepting a product if presented in the same way as for the group on its left side. The important learning from this figure is the big gap – *the chasm* – in between early adopters and early majority. According to Moore [27], "this is by far the most formidable and unforgiving transition in the Technology Adoption Life Cycle, and it is all the more dangerous because it typically goes unrecognized".
2.3.6 Survivorship bias

Survivorship bias is the error of focusing on the people or things that passed some selection process and discount for those that did not pass [28]. This bias can lead to false conclusions. In the context of this thesis it might be applicable to the process of selecting interviewees among the current customers for finding insights and evaluating the prototypes against. The current customers have in fact chosen to invest in solar panels, hence the ones that did not despite given the opportunity are ignored. There might be a group of potential customers, possibly greater than the current ones, that if taken into consideration could have been able to attract.

2.4 Visualizing information

When presenting information to the customer, there are different decisions to be made regarding what, how, where and when information should be visualized. Below are different areas that will be considered when dealing with such questions.

2.4.1 Design approaches for energy visualization

Anderson and White [29] distinguish between three different ways of presenting household energy consumption.

- **Numerical displays** – These displays focus on numerical data and can therefore be very accurate.

- **Analogue displays** – These displays illustrates the numbers in terms of graphs and other graphic elements.

- **Ambient design** – This design approach is not about detail, it is intended towards the peripheral vision. As the example in Figure 7c, it could be in the form of a lamp that for instance change color based on some variable; green for "good solar production", red for "no solar production" and gradients for in between. It could however be implemented in completely other forms as well.
2.4.2 Feedback system

According to Norman, a fundamental design rule is to provide continual awareness, without annoyance [30]. The effectiveness of feedback with the desired effect of reducing electricity consumption varies widely across different studies. Some have concluded that feedback alone not often is sufficient enough to reach this effect, sometimes even resulting in the opposite [31]. Froehlich [32] has come up with ten design dimensions to consider when designing a feedback system:

1. **Frequency** – The frequency of which a feedback system informs the user seems to enhance the user’s awareness about their action’s effects.

2. **Measurement unit** – Choosing a measurement unit that the user can relate to can help her or him to understand the feedback better.

3. **Data granularity** – The resolution of the data that is presented to the user. For example time frame (per hour, per day), space (kitchen, ground floor), source (vacuum cleaner, coffee machine) or source category (heating, lights). He states that Dennis speculates that it is essential to link energy consumption to energy source, “part of the reason that feedback is not more effective appears to be that consumers do not know what each component of their electricity consumption costs” [33].

4. **Push/pull** – Should the feedback system provide information at all time (for example through a display), inform the user at specific moments, or should the user actively have to visit a website, app or such to retrieve the information? Or perhaps a mash-up of both?

5. **Presentation medium** – In what medium should the data be presented? On paper (for instance on the electricity bill), electronic displays, or tangible ambient displays? The latter cannot provide as much detail as other mentioned mediums, but Froehlich believes that it is likely that highly accessible information would be
best for getting awareness. The author adds that Latham and Locke means that awareness alone does not always lead to behavior change [34].

6. **Location** – Where should it be presented? At the appliance it is measuring, or somewhere else inside (or outside) the house?

7. **Visual design** – In what manner should the data presentation be designed? Froehlich discusses two general types of visualization; pragmatic and artistic.

8. **Recommending action** – Should the system provide recommendations (for example, tell the user to turn off lightning to save electricity)? If so, he means that specificity, timing and placement is essential.

9. **Comparisons** – Giving the user methods to compare performance to the past is important, according to Froehlich. He further states that comparisons for electricity usage should be normalized according to weather (colder days means bigger needs of heating, for instance).

10. **Social sharing** – Should some of the information be shared on social media, for instance the energy consumption? Froechlich states that the user may feel pressure to lower the consumption because of this.

### 2.4.3 Different types of graphs

There are many different graphs to choose from when data is to be visualized. We have to distinguish between instantaneous data and data visualized over a time axis. Both of which are of interest in this work, since it might be wanted to choose between seeing production and consumption right now as well as over a previous period of time.

**Line charts**

Gleicher et al. observes in their research that visual design of graphs comparing two data-sets fall into three categories; *juxtaposition, superposition* and *explicit representation of the relationships* [35]. They further divide the third category into two sub categories; explicit encoding showing the difference over time, and explicit encoding with a time warp alignment. These categories are not unique to line charts, they could also be applicable to bar charts for instance – however they are most obvious in line charts, hence they are discussed under this segment. See Figure 8 for visual examples of the different categories.

The categories in Figure 8 are described as:

- **Juxtaposition** – This design puts the objects separately in different graphs. The actual comparison requires the observer to shift the attention between the graphs and determine their differences.

- **Superposition** – This design puts the objects on top on each other, in the same graph. They can be distinguished by color or form for better readability.
• **Explicit encodings** – This design category shows some relationship between the two objects and presents them in one graph. Figure 8.c represents the subtraction of the two data-sets, and Figure 8.d represents a time warp alignment.

**Horizontal bar charts**

Knaflic writes in her book *Storytelling with Data: A Data Visualization Guide for Business Professionals* [26] that if she had to pick a single graph for categorical data, it would be the horizontal bar chart (see Figure 9).

Meanwhile, Godau et al. state that vertical bar graphs are reported more user-friendly than horizontal ones [36].

**Grouped Dot Chart**

The study "Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods" investigates how multiple sets of data best can be presented in order for the observer to quickly get a good picture of it. Based on the criteria that the main goal of reading graphs not is being able to read the data with as high decimal precision as possible, but to take in and organize the information and see patterns that are not readily revealed, Cleveland and McGill [37] claim that a grouped dot chart is the best way of portraying parts of a whole (see Figure 10). Much like the horizontal bar chart in Figure 9 it is a horizontal variation of the common bar chart. However, the grouped dot chart includes a sum of the subsets within the different
categories, and the "bars" are created by dotted lines with a bigger dot at the end.

Pie charts

One of the most commonly used graphs for comparing relative sizes of the parts of a whole is pie charts [37]. Cleveland and McGill [37] believe that the primary fundamental visual task for extracting the information is perception of angle, but probably also areas and arc lengths of the pie slices.

In pie charts with more than two slices it can be difficult to determine the relative sizes in between – especially if they are close to each other in size. Look at Figure 11 and try to rank the slices of the pie chart in order of size. Compare that task with doing the same with the bar chart in the same figure. It is in this case easier to do with the bar chart, however with only two values to compare the task of judging which slice is bigger may be easy with a pie chart – to get a feeling for how big the difference is might still be easier with a bar chart. But reducing time and cognitive load may in some cases be of greater interest than seeing the exact numbers.

In the study "Perception of bar graphs – A biased impression?" Godau et al. write that there are extensive studies on several different kinds of data graphs, some of which show for instance that bar graphs can be read both faster and with higher accuracy than pie graphs [36].
Filip Hammarberg
id12fhg@cs.umu.se
Visualization of electricity consumption and solar panel production for house owners
June 11, 2018

Figure 10 – Grouped Dot Chart [37] p 548

Figure 11 – Pie Chart and Bar Chart [37] p 533

Speedometers

Speedometers, or speed meters, are derived from vehicles and have the purpose of measuring and displaying the instantaneous speed of a vehicle. See Figure 12 for an example of a speedometer. This type of visual representation of varying values is nowadays being used outside the vehicle industry as well, see Figure 13 for an example from the app Bredbandskollen [38], an app for measuring internet speed.
Figure 12 – Example of a speedometer

Figure 13 – Implementation of a speedometer in the app Bredbandskollen
2.5 How others have done

Although this thesis will take off from the customer needs found when interviewing the customers, it is still of interest to see how others have handled similar challenges prior to this work.

**Fronius app ("current app")**

The supplier of inverters to Umeå Energi’s solar panel customers, Fronius [39], provides an app to smart phones. Within the app the user is presented with instantaneous power as well as charts plotting energy yield and power over time. See Figure 14 and 15 for screenshots from their Iphone app.

**E.ON app**

The energy company E.ON [40] provides their customers with a smartphone app [41]. It
offers the possibility to compare electricity consumption on a monthly or yearly basis, as well as it provides temperature data to give a better understanding on how the weather affects the electricity consumption. The app also has a function called "neighbour comparison" where the user's electricity consumption is compared to similar houses, and the function helps the user to create an action list for improvements in order to lower the consumption. Apart from the electricity consumption, the app also provides information on invoicing, contracts and power failures.

All mentioned above is part of their free version of the app, but they also provide a premium version called 100Koll. It gives the user real-time electricity consumption data, as well as it divides the consumption into different appliances. This requires hardware with a sensor on the electricity meter that reads its diode which pulses in different frequencies depending on consumption load.

Since only customers to E.ON have access to their app, no screenshots have been collected.

**Watty**

Watty is a service that works similar to the premium version of the E.ON app described above. With a sensor placed on the electricity meter’s diode, it reads the electricity consumption. It then uses machine learning to separate the consuming devices from that one signal, and presents it to the user in an app.

Since only customers to Watty have access to their app, no screenshots have been collected.
3 Method

This section describes the way this work was conducted.

3.1 Literature study

Prior to meeting with the users, a literature study was performed. Books and research reports related to this thesis were read and used to build a theoretical framework. This framework will be referred to and used for making decisions further on in the carrying through of this work.

3.2 Design method

The overall design method that is being used in this work is based on the service design methodology. That is a collection of design oriented methods aiming for a holistic view of a user’s touch points and interactions with an organization or a service [42]. This work is focused on a specific task within a greater project, hence the holistic view will be narrowed. The main components of the service design methodology will still be used to the greatest extent as possible within this part.

The design process used by Daresay is illustrated in Figure 16. It consists of four main parts; explore, conceptualize, design and evaluate. This is used as a basis to the process of this thesis, which is illustrated in Figure 17 and in detail described in sections 3.2.1–3.2.8. The set-up of the work of this thesis is illustrated in Figure 17.

![Figure 16 – Design process at Daresay.](image-url)
3.2.1 A. Investigate needs, context, behavioural groups.

After the literature study, the design work will initially be based on insights from interviews with the users. The idea is to not start with a biased approach, but to find the underlying needs to their requests formulated by Umeå Energi. The decisions made further on will then hopefully be more well-informed. The interview questions from this session can be seen in Figure 18. The interview questions should be seen as a ground for a conversation rather than a list that will be read literally. A list of solar panel customers was selected and delivered from Umeå Energi, whereof two initially were contacted.
OM MIG OCH HUR INFORMATIONEN KOMMER ATT ANVÄNDAS

 jag skrev examenarbete på programmet Civilengynjor med fokusering Interaktion och Design.

Sökesuppläteger gir ut på att förstå hur de har arbetat med produktion och konsumtion på bostadshus. Denna studie har resultera.

Svenska skriftverk kan härskeras att legga till grund för kommersiella arbete kring detsu, med att nåts i att skapa prototypes.

Om möjligt skall jag göra en gestrik av hur orsaker kring dessa prototypes.

Svenska kan kunna att att, ansöknings- och omvandning-process, samt rapportering på olikt områden eftersom även.

Om dig...

Namn: __________________________

Älder: __________________________

Familjefaktiska: __________________________

Iblanden: __________________________

Uppmärksamhet: __________________________

BAKGRAUNDSINFORMATION

När det gäller Unam-Energy...

Hur sydor du att det är som levererat? (Värdför)

Vid du att dagen avslutat?

Hur talar du att alarma av att i fortsättning? (Värdför)

När det gäller dessa saker...

Vidför skrädder du så perspektif?

Hur svarar du på tekniken?

Vidför att Unam-Energy som levererat?

Hur skulle att skänka mer med dina skånsar av att?

BEHOV

När det gäller alproducierens från satsningar kontra affärsvykortet i huset...

Har det andra en förbrukning vidare du med att producera själv?

Vad vill du upp? (Värdför)

Vilka frågorna är mest intressanta (värdefull, varandra, bra, tre, dag och?) (Värdför)

Vad ska du använda det informationen att? (Värdför)

Skulle du vilja jämföra der produktion och eller konsumtion med andra leverantörer? (Värdför)

IKONTEXT

När det gäller alproducierens från satsningar och affärsvykortet i huset...

Var levererar du dig när du vill vika det? (Värdför)

Vad vill en allmänt vilja att vika det? (Härfor ju)

Figure 18 – Basis for initial interviews (in Swedish)
3.2.2 B. Define behavioural groups.

Daresay has gone from using personas to behavioural groups. Nielsen Norman Group defines a persona as "a fictional, yet realistic, description of a typical or target user of the product. A persona is an archetype instead of an actual living human, but personas should be described as if they were real people."[13]. Daresay means that people tend to attach personal, sometimes irrelevant, experiences towards specific personas if the it reminds of some person they have met in real life. Behavioural groups solves this by extracting the describing elements of the persona and treating it as a set of properties instead of projecting them on a fictive person. A behavioural group can also include context as a variable; people can have different needs and behaviours depending on what context they are in, which personas does not take into consideration.

3.2.3 C. Define needs, context, measuring unit, resolution, time window.

Based on the insights from the initial interviews with the customers, customer needs, context and service goal will be formulated.

3.2.4 D. Involve Umeå Energi.

At this stage the insights so far are compiled and delivered to Umeå Energi. The purpose is to inform them where we currently are in the working now and where we are heading. Comments will be collected and brought into the next stage. At this point, it would be profitable to involve Umeå Energi even more – for instance by arranging a workshop where we together try to analyze the insights – but due to the limitation of time, mentioned in section 1.1.3, this has been reduced to a checkpoint of this kind.

3.2.5 E. Investigate how the data can be visualized.

This is where the key part of the design process starts; finding the best way to visualize the data to fulfill the service goal. The findings from the initial interviews may very well change the following questions, but to start with they are formulated as follows:

- Are production and consumption the core values?
- Which measuring unit should be communicated? kWh? SEK? Comparisons?
- What types of diagrams are most suitable?
- At what resolution should focus be? The entire building, selected rooms, selected devices? Or a chosen device or room to compare against?
- How big should the window be for live view? Instant data may not give much insight. Latest hour/day/week?
3.2.6 F. Create prototypes based on insights from E.

Low fidelity prototypes pointing at different directions are created. Too much work in terms of visual design is not being put into creating them. They serve as triggers with the main purpose of opening up for conversation with the users regarding their understanding, behaviours, needs, problems and for finding better solutions. A successful prototype that encourage telling is similar to a sentence cut in half where the user fills out the end [44].

Low-fidelity prototypes, in particular, are rough representations of concepts that help us to validate those concepts early on in the design process. [45]

Ewerman states that prototyping with user involvement gives much better results than, as often occurs, thinking by yourself and arguing for your own ideas in meetings [44].

3.2.7 G. Evaluate prototypes together with users.

As Nielsen and Norman [46] write, "Many organizations claim to be user-centric. Yet they fail to include users in the development process. Without customer input, organizations risk creating bad interfaces".

The prototypes will be evaluated together with customers and the insights will be taken into consideration for each new iteration. The evaluation will consist of usage observation and interviews during and after the evaluation.

3.2.8 H. Evaluate the result.

The final prototype will be discussed in this thesis and final insights will be presented. It is likely that the final prototype will not be considered as a production-ready version, but rather be a foundation together with insights for future work in this area.
4 Results

Below are the results that have emerged from the work described in the Method section.

4.1 Insights from Umeå Energi’s pre-study

Some work regarding the solar panel customers have been done by Umeå Energi prior to this thesis. A meeting was held with Umeå Energi where internal, anonymized, documents from their customer interviews and workshops were presented. Umeå Energi had met with a total of six of their current solar panel customers. These documents have been analyzed from the point of view of this thesis, below are the findings that have emerged from that.

The interviews conducted by Umeå Energi revealed attitudes towards the reason why the current customers chose to invest in solar panels. The reasoning among the interviewees follows a pattern with a common denominator that can be described as caring for the environment. Below are quotes from an internal document at Umeå Energi, containing the interviews (translated from Swedish) that summarize these attitudes.

"The purpose is to contribute to the environment in a positive way"

"I want to be self-sufficient"

"It feels good"

"I think about the environment and sustainability"

"I want to contribute to making it better"

"I did not do it because of the money"

"We want the kids to being able to tell in school that they care about the environment"

Regarding the surplus from the solar panels, the interviewees seem to have similar arguments among each other; the over-all consensus is that they would rather use the electricity produced themselves than selling it back to Umeå Energi. Below are quotes that summarize these opinions.

"I’d rather be self-sufficient than getting payed"

"If feels better using it myself than selling it"

"The best would be if one can use the surplus to the one owns consumption"

"One has to be sure that the consumption is big enough"

"In the future I have nothing against having a big battery in the garage that can store the surplus. That way I can store the electricity over night."
"I think the excess production’s buy-back price will approach zero, as more people get solar panels"

Regarding the economical incentives, the customers seem to have a mutual approach in this area as well. Below are quotes related to this.

"We are not doing it to get a cheaper electricity bill, it’s not about earning money"

"I won’t make any money off of it, but it feels good"

"It doesn’t matter whether we earn or lose a couple of hundred SEK per month"

"I don’t think the panels will pay for themselves unless the electricity cost will increase"

"I didn’t get the panels for earning money"

### 4.2 Interviews and insights

When interviewing the customers for this thesis, the insights from Umeå Energi’s prior work have been confirmed and some in more detail discovered. The following insights emerged after the first interview sessions with three of their customers:

The customers want

- to be able to track progress of the production and consumption,
- to be self-sufficient,
- to do good for the environment,
- everything to work without problems.

When digging deeper into the desires above, it was found that most of the needs were grounded in the fact that they want to be self-sufficient; tracking progress of the production and consumption has the purpose of being able to maximize the self-sufficiency. To do that, the customers want to have access to some sort of historical and live view over the data. Doing good for the environment in this context is equal to being self-sufficient – by being that, the consumption of electricity produced with fossil fuels is lowered and therefore the environmental incentive gets fulfilled.

Two conclusions were initially drawn from the insights from both Umeå Energi’s prior work and the first interviews conducted for this thesis that might be able to benefit from each other. Both of these has the purpose of becoming more self-sufficient as mentioned above.

1. The customers want to be able to see the production and consumption in different time perspectives, one of which is historical view.
2. The customers would rather use the electricity produced themselves than sell it to Umeå Energi.

One selling point that Umeå Energi is using in their communication for their solar panels is the fact that the surplus will be sold back to Umeå Energi [47]. In other words, when the solar panel production exceeds the consumption, the customers can save money. This seemed however not to be the general attitude among the customers, based on the insights presented above; as mentioned, they would rather use all of the production themselves than selling parts of it.

This opinion might at a first glance be based on the fact that the sell-back price currently is lower than the cost for buying electricity. In other words, the customers would economically benefit from planning their usage so that the surplus peaks are covered with consumption that would have taken place anyway. But, according to the insights above this seems to be related to the customers need of being self-sufficient rather than related to money. That being said, when creating the first prototypes, the communication should probably be focused towards the self-sufficiency rather than economical incentives.

To illustrate this reasoning, imagine that the customer has access to a historical view of their consumption and production for, in this example, one day. This is visualized in Figure [19]. As seen in this figure there is a surplus peak at one part of the day (marked with a checkered pattern), followed by a bigger consumption peak later on.

![Figure 19 – Example of production and consumption for one day](image)

Based on the assumption that the customers would rather use all of the production themselves, it would have been desirable that this scenario was played out differently. If the consumption peak would have been shifted so that it covered the surplus peak, the
customer would have been using all of their produced electricity themselves. See Figure 20 for an example.

![Diagram](image_url)

**Figure 20** – Example of preferred production and consumption for one day

The first scenario illustrated in Figure 19 could have turned out as the one in Figure 20 if the customer had the tools to predict the surplus peak. Having access to a view over consumption and production of this sort, either the service itself or the customer could (at least in some cases) forecast the moment where the two curves are about to intersect and having less electricity consumption than there is production. Note that the idea not is about consuming more electricity, but having the tools for being able to plan the activities in order to maximize the self-sufficiency.

### 4.2.1 Behavioural groups

Described further in section 3.2.2 behavioural groups is a set of properties describing different personalities within the target group. As a result of evaluating the interviews conducted with the customers, and the material provided from Umeå Energi, the behavioural space which the customers fall within has been defined using two parameters:

1. The ongoing engagement of the production and consumption
2. The knowledge and/or interest of the solar panel technology

A third parameter that was looked into was *incentive*, reaching from economical to sustainable. However, from the provided material from Umeå Energi as well as from the first interviews conducted for this thesis, there was no divergence in this parameter. None of the interviewees expressed any economical incentives, instead the consensus was that
they were doing it for sustainability. Hence the sustainability factor covers all four behavioural groups. From the two parameters above, four groups have been defined based on the insights:

- **Humble** – Feels like it is a good thing to do. Has noticed that the electricity bill has been a bit lowered.
- **Comfortable** – Has made calculations on it and trusts that everything works well. Checks the data once in a while.
- **?** – Does not know how it works, but wants to make sure that it does.
- **Meticulous** – Is familiar with the technology and is interested in ongoing status updates.

Among the customers, no one was found to fall under the **Humble** category. This was expected due to the earlier mentioned reasoning in sections 2.3.5 and 2.3.6; the current customers are early adopters with either knowledge or interest in the technology, or want to track progress on how the solar panels are working. Otherwise chances are low that they would have gone through the process of getting solar panels in the first place. This category of customers might however still be of interest to Umeå Energi, as they are expected to show up among the customers in the future. They can be seen as the next generation of users, buying houses that happened to have pre-installed solar panels. They
can also be seen as other members of the household that was not involved in the process of getting solar panels. In Figure 22 below are the different behavioural groups described in more detail.
"No red light blinking on the inverter, it seems to be fine."

**Humble**

**Knowledge/interest:**
Has neither interest or knowledge about the technology. Did not actively acquire solar panels.

**Expectations:**
No particular, just wants the solar panels to be functioning.

**Behavior:**
Is not explicitly involved in the solar panel production; but has noticed that the electricity bill has a field for production and that it has lowered the cost.

**Needs:**
Not having to invest time or effort in the solar panels.

"By reducing the indoor temperature I approached free heating."

**Comfortable**

**Knowledge/interest:**
Has interest in the technology and is familiar with the terminology. Knows what to expect in terms of kWh, but not in detail how it works.

**Expectations:**
That the solar panels over time will produce as expected based on own calculations.

**Behavior:**
Evaluates the outcome occasionally. Makes changes to their behaviour to be more self-sufficient, when patterns have emerged.

**Needs:**
To get confirmation over a larger time scale (month, year) that the solar panels are producing as expected as well as how changes to their behaviour alters the consumption.

"Why does my neighbour produce more electricity than I do?"

**?**

**Knowledge/interest:**
Has no knowledge of how it works, or interest in the technology itself.

**Expectations:**
That the solar panels are producing the estimated amount of electricity provided by Umeå Energi.

**Behavior:**
Thinks in terms of SEK to relate to the electricity bill, and kWh to relate to the given production estimate.

**Needs:**
Confirmation that the solar panels are working and producing electricity as promised. Quick access to support. Afraid of getting tricked.

"I cut down some branches and increased the production."

**Meticulous**

**Knowledge/interest:**
Has good knowledge of the technology and a lot of interest in solar energy and self-sufficiency.

**Expectations:**
That he/she is getting the maximum amount of energy from the solar panels as possible.

**Behavior:**
Is following the production carefully. Makes ongoing adjustments to their behaviour in order to become more self-sufficient. Removes snow from snow panels by winter, cuts down branches that covers the sun. Makes contact with Umeå Energi when there are questions.

**Needs:**
To get detailed information providing the opportunity to track progress and make changes to maximize the production and minimize consumption. Quick access to support.

---

**Figure 22 – Behavioral groups, description**

34
After defining the behavioural groups, they were mapped to the different insights as seen in Figure 23.

![Figure 23 - Behavioral groups, requests](image)

As shown in Figure 23, the first two insights has suggestions for meeting the respective needs. When ideating on the remaining three needs an idea was formed which consisted of a new measuring unit. That unit could potentially meet all of the three remaining needs. It was initially called *the self-sufficiency meter*, with the purpose of communicating what extent the customer has been self-sufficient in a certain time period. See Figure 24 for the first draft of that meter. It has several purposes:

- Present level of self-sufficiency.
- Present level of environmental goodness.
- Give an indication on if the solar panels are working or not.
- Being a tool for ambassadorship, giving the customers a simple unit for communicating the solar panel’s outcome to people with less knowledge in electricity consumption.

35
4.2.2 Measuring unit

The commonly used unit for measuring delivered energy is kilowatt-hour (kWh) which is defined in section 1.2. In the material provided from Umeå Energi, the overall attitude towards the kWh among the customers is that it is a good choice of measuring unit. However, some of them argued that conversion to a currency (the one they are being billed with) might be more broadly understood. One of them would also like to have the possibility to convert it to the distance which one could drive an electric car. Below are quotes from Umeå Energi’s internal document containing their interviews with their customers (translated from Swedish).

"I’m used to think in terms of kWh, don’t think that you have to translate it to something else. However, it could be an idea to use references to other things."

"I’m pretty familiar to the concept of kWh and don’t need any translation, that would just mess it up."

"It would be intreseting to compare the electricity production with how many miles I could travel with my car. That’s how I usually explains it for others."

"Through the current app you can see how much CO₂ you are saving, and that’s fun. I think that people are starting to get a feeling for what it means. But just an amount can be hard to relate to, would be better to relate it to some other amount."
"I believe that it works fine relating to kWh. Most people probably have a feel for roughly how much one is consuming."

When interviewing customers for this thesis, the consensus for using kWh as the measuring unit was confirmed. Some of them argued that currency at first glance might be suited as well, but that one would have to take different circumstances into consideration when looking back – making it not a good choice of unit. Such circumstances could be pricing at the time, inflation and taxes. A kWh on the other hand, is the same today as ten years ago.

4.2.3 Resolution

One of the interviewees would like to split the energy consumption into two parts; heating of the house, and household electricity. This way, he argued, the electricity consumption by the appliances would not drown in the total consumption. That would in turn make it easier to spot when for instance a newly purchased appliance is consuming more electricity than desired or expected. He also stated that it would give him the possibility to evaluate how much lowering of the temperature would decrease the electricity consumption.

4.2.4 Time window

The customers seem to be driven by two different reasons when it comes to choosing an appropriate time window for viewing the data. One on hand they are interested in seeing it on a fairly large scale, like on a month basis, for drawing conclusions on their consumption and production. This was found during the investigation of customer needs and was explicitly stated by several interviewees. On the other hand, a majority of the interviewees would also like to be able to see the information in a much smaller time window, like the latest hour or even instantaneous data. There were no needs found earlier that would favour this time window, instead this was found when talking about what time windows that were of interest among the interviewees. When following up on why this seemingly non-profitable instantaneous data is of interest, the only common denominator that was found is curiosity. When going deeper in this matter with further questions, it seems like that curiosity has the goal of learning the circumstances that play role in different production levels. For instance, learning what difference it makes that the sky gets cloudy on a sunny day.

One of the interviewees argued that seeing anything less than one month of data is of no interest, since no patterns can emerge from any smaller information basis. Another interviewee made a reference to driving his car; "When driving, I'm not only interested in the average fuel consumption for the last ten kilometers. I'm also interested in seeing the instantaneous effect that pressing the gas pedal makes on the fuel consumption. That helps me to get a better understanding for how to drive the car in order to minimize fuel consumption."
4.3 Touching basis with Umeå Energi

A meeting was held with Umeå Energi where the insights above were presented. The purpose was to give them an update and hear if they had any questions or opinions before proceeding with prototypes. They were positive and the work continued.

4.4 Visualizing consumption and production

When visualizing data that met the needs found earlier, two types of visualization was needed:

1. **Continuous data**, for presenting the ongoing production and consumption for different time frames.
2. **Summed data**, for presenting the total amount of production and consumption for different time frames.

**Continuous data**

Different graphs showing mock-up data was created with Google Sheets and got presented for the interviewees, as seen in Figure 25. All figures represent production in green and consumption in red.

- **Figure 25a**: Vertical bar chart
- **Figure 25b**: Horizontal stacked line chart
- **Figure 25c**: Horizontal line chart
- **Figure 25d**: Horizontal normalized stacked bar chart (only the ratio between the production and consumption can be read, no absolute values)
- **Figure 25e**: Horizontal area chart
- **Figure 25f**: Horizontal normalized area chart (only the ratio between the production and consumption can be read, no absolute values)
The interviewees preferred graphs a, c and e shown in Figure 25. Since the graphs were exported straight from Google Sheets, details regarding the visual representation were not of interest at this stage.

**Summed data**

Different graphs showing summed data was presented for the interviewees, as seen in
Figure 26 All figures represent production in green and consumption in red. The gray bars are subsections of the consumption; household electricity, hot water and heating. The interviewees were at this stage least interested in pie charts, but had no particular preference in whether the bar charts should be horizontal or vertical.

4.5 Prototypes, iteration 1

The first prototypes that were presented to the customers were at a basic level. Their purpose was to try two different design directions; one with customization possibilities and few elements, and one with little customization but more elements. The idea was to find out if the customers would prefer to interact with the system in order to get the
information requested, or would they rather have much information presented at once with the drawback of having a greater cognitive effort finding the searched elements.

Different parts in the prototype were left empty and gray on purpose, to serve as triggers letting the customers fill in what they would like to see there.

![Diagram](image)

**Figure 27** – Prototype, iteration 1. Direction: simple but customizable
The self-sufficiency meter (Figure 24) was shown to one of the interviewees and got good response. That concept was ideated in between the interviews, hence only one got to see it in the first interview round. He figured that not only does it give him a quick report on how well the solar panels are producing electricity – he also reasoned that it would be a great tool for showcasing the solar panels to neighbours and friends. He meant that a percentage over self-sufficiency is a language that everyone understands, making it easier for him to be an ambassador for the product. He said "When my neighbour asks how the panels are doing, I can simply show him that – 'here, look, last month I have been 50 percent self-sufficient!' – everyone understands that."
4.6 Insights from prototypes, iteration 1

After presenting the first prototypes and examples of data visualization to the customers, some new insights were found. One was that they were interested in *comparisons* between different time intervals. The favorite design direction among the met customers was the simpler one with options and only one view. They were however attracted to the comparison element in the other design direction, and asked for a way of combining the two directions. They wanted to be able to compare years by each other, and months from different years. The reason was to find changes that they could learn from in order to minimize their consumption or being able to make better predictions regarding their production.

4.7 Prototypes, iteration 2

When implementing the self-sufficiency meter into the prototypes, some problems appeared regarding its functioning. As mentioned before, the electricity produced gets discounted from the electricity bill by the amount of kWh produced. One kWh of production leads to one less kWh being payed for. But if there is a surplus (production greater than the current consumption), that production gets sold back to Umeå Energi at a lower price than for what electricity is bought from them.

This creates the problem that the self-sufficiency cannot be calculated by taking the ratio between produced and consumed kWh – if self-sufficiency is defined as *not having to pay for electricity*.

To investigate how the customers would interpret the self-sufficiency meter in a real scenario having the reasoning above in mind, phone interviews were conducted with two of the customers prior to meeting them again. A hypothetical scenario was presented as follows:

Assume that the electricity price is 1 SEK per kWh, and the buy-back price for surplus is 0.35 SEK per kWh. Imagine a week where you have consumed electricity worth 100 SEK, where 80 percent was covered by solar production. That same week, you had a surplus production that was sold to Umeå Energi for 10 SEK.

In other words:

- Gross consumption: 100 SEK
- Net consumption: 20 SEK
- Surplus production: 10 SEK

Out of the 100 SEK, the invoice was only 10 SEK. How self-sufficient have you been?
With the assumptions above, the surplus production was 28.6 kWh. That puts the self-sufficiency level at 71 percent when calculating with kWh, but 90 percent when calculating with SEK. This could of course turn out the other way: Let’s say that you consumed 100 kWh of electricity one time period with no solar panel coverage, and within that same period produced 200 kWh when there was no consumption at the same time. By counting kWh you would have a self-sufficiency level at 200 percent, but when counting SEK it would only be around 14 percent.

The customers who were asked about this had the same answer – the percentage of the lowered amount on the electricity bill is what they think describes self-sufficiency best. One said "Sure, I’m doing this for the environment and don’t care if I lose some money by doing so. But getting an invoice that I have to pay, and at the same time be told that I’m 100 percent self-sufficient feels wrong".

The work-around for this problem was to present the self-sufficiency in terms of invoice crediting, and also present the amount of surplus kWh that were sold back to Umeå Energi. Below are images from the second iteration of prototypes. This time they were implemented in a prototyping app, Invision [49], making it look and feel like an iOS app. It was presented on an iPhone 7 Plus.

As seen in Figure 29, the app consists of five different time windows in which the data can be viewed:

1. Year
2. Month
3. Week
4. Day
5. Right now

The prototype only had the Month and Right now time windows working. In the Month view, two different months were able to change between. One insight that was found in the first prototype iteration was that the customers wanted to be able to compare different time periods. Therefore an option to do so was implemented, and is shown in the middle picture in Figure 29 comparing the same month from two different years. The user can choose what time period to compare against in the "Compare with" drop-down menu.

The right hand image in Figure 29, the Right now view is shown. This presents instantaneous data and the graphs are subject to change every other second or such.
4.8 Insights from prototypes, iteration 2

The prototype (iteration 2) was presented to one customer. His response was positive, and he liked the fact that he could compare different time periods to one and other. One thing that he missed however, was a way of being able to read the data from the graphs in plain numbers.

While observing the customer using the prototype, it was found that he had to put down some effort in reading the data within the design. When asked about how he thought it was to find what he was looking for, he stated that he found it easy to comprehend but sometimes had to think twice to correctly find and read the data from the figures.

4.9 Prototypes, iteration 3

In the third iteration of the prototype the main changes were:

- The horizontal bar chart, visualizing the summed data of the selected period, is changed to a vertical bar chart.

The initial decision to make those
bars horizontal was due to saving space and thus reducing the need of having to scroll. Having it horizontal would align better visually with the right now view, so it was changed on trial to see if the need of scrolling was disturbing the customers.

- **The visual design follows a grid more properly.** The goal is to give the customer a better way of finding and reading the data.

- **The icon for amount of sell-back electricity is changed to a plus sign.** The prior symbol in iteration 2 was questioned by the interviewees, they thought it was unclear what it meant. This new symbol is supposed to match the meaning better.

- **The self-sufficiency meter has green and red color in it.** This positive meaning within the green color representing production in the summed data is transferred to this element as well, in order to make the comprehension better.
4.10 Insights from prototypes, iteration 3

The parts in the prototype that presents self-sufficiency and surplus production does not seem to be clear enough. The interviewees were still struggling to exactly understand the core of the data. This seems to be related to the difficulty of defining self-sufficiency discussed in Section 4.7.

The surplus area in the area charts was unchanged in this iteration, but the interviewees expressed that they felt somewhat obscure. Especially in the comparing view when line charts are added on top.

One of the interviewees asked "so now when I have all this information in a table form, which I asked for, what do I do with it? I might find the bad months but I have no clue
what the reasons behind them are”. He stated that he would like to be able to add events to the app that could have an impact on his energy consumption (such as kids moving from home, new white goods etc.).

4.11 Prototypes, iteration 4

This iteration is made upon insights from the prior iteration, but has not been tested with customers nor will be in the framework of this thesis. The main changes in this iterations are:

- **The area charts are replaced with line charts.** The insights from the earlier iterations found that the surplus area was hard to perceive. This way the surplus area is the only area using background color, making it easier to distinguish from the rest.

- **Outdoor average temperature and solar irradiance (solar exposure) are added to the bottom chart containing data in the different views.** The idea is to collect this data from third parties (for instance SMHI [50]) considering it relevant information for understanding the fluctuations in the data.

- **The comparison view is split into two views, separating consumption and production.** The earlier iteration with both of which compared within the same view was experienced cluttered by the customers. In this view, the user can scroll horizontally in the bar charts to explore different time periods. In the line chart, any number of time periods can be marked to be shown on top of each other. And finally, in the table view the user can scroll horizontally like in the bar charts at top.

The changes in this iteration are the most extreme up to now. It is a completely new way of comparing the data, and the table view contains much more information than earlier.
Figure 31 – Prototype, iteration 4.
5 Discussion

This section discusses the outcome of this thesis based on the theoretical framework on which decisions were based upon, and the method used for carrying it out.

5.1 Method

Findings and reflections from the method used are discussed below.

5.1.1 Literature study

As a foundation for the work to be performed in this thesis, a literature study was initially performed. This aimed to provide understanding in the area, as well as accumulate prior knowledge from others who had performed work related to this task. Finding relevant research was not completely straightforward, since the specific task within this thesis was not earlier investigated into any greater extent. There was however lots of relevant information to gain when the task of the thesis was divided into sub-tasks such as information visualization and service design.

5.1.2 The service design methodology

The design method that was used in this thesis has been a great tool. Having access to tools such as The Five Whys (2.2.1) has been helping with getting to the core of the interviewees’ needs and thoughts. There are occasions where, repeatedly asking why to interviewees, answers has led to insights that otherwise probably not would have been discovered.

Not rushing with creating prototypes has been rewarding; some of the earlier assumptions regarding the look and feel of the result turned out to be wrong. Thankfully this was only thoughts, and due to following the path with gaining enough insights from the customers before starting the prototyping phase they were never carried out.

The iterative process used in the service design methodology has further been key to not be drawing conclusions to soon. Constantly keeping in touch with the customers, asking questions and testing ideas, seems to have led to a result that matches their expectations fairly well.

5.2 The result

In the latest prototype iteration, the amount of information available to the customer has increased from the prior iteration. Choosing that amount was discussed in section
with the learning that we should limit the cognitive burden on the user so that he/she do not have access to too much information. That learning speaks for the fact that this iteration may have gone too far in this regard.

Even if the prototypes meet the expectations of the solar panel customers of Umeå Energi today, it is important to think about the product adoption cycle discussed in 2.3.5 when continuing on this work. This applies to the amount of information discussed above, as well as many of the other decisions that have been made along the way. The preferred measuring unit for instance may vary when asking the next generation of customers, being something else than the kilowatt-hour. Independent on which measuring unit that is used, additional comparisons in other units may also be of interest. That is something that has not been carefully investigated. For instance, there could be an explanatory part that compares the kilowatt-hours to different things, much like Project Sunroof [51] does. They present the potential impact, comparing the produced kWh to amount of avoided CO₂ emissions, number of passenger cars taken of the road for one year and amount of tree seedings grown for one year.

One of the interviewees had problems distinguishing some of the different data-sets in the area graphs due to color blindness. As discussed in section 2.3.4, around 8 percent of men and 0.5 percent of women are color blind. Not taking such limitations into account is one of the limitations of this thesis, as discussed in section 1.1.3. This is however important to consider in any future work.

It was stated in section 2.4.2 that it is important to provide the user with methods to compare performance to the past. This desire has been found among the interviewees as well, and have been implemented in the prototypes. It was further stated in section 2.4.2 that the comparisons should be normalized according to weather, making it possible for the user to compare a winter day to a summer day in terms of energy consumption. When talking to customers, that normalization does however not seem to be requested or appreciated. The conclusion drawn in this area is that the customers want the data as raw as possible (yet understandable), to draw their own conclusions rather than having to compensate and understand the assumptions made from the system. And they further stated that they do not want to compare different months to each other (i.e. January to June), but rather comparing specific time periods with the same periods earlier years (i.e. January 2017 to January 2018).

In section 2.4.2 so called recommending actions were discussed. Should the system for instance provide the user with recommendations on when to turn on or off appliances in order to maximize the customer’s self-sufficiency? This has not been carefully investigated, yet it seems like the customers have interest in this when asked about it. This could be further investigated together with the push/pull discussion in the same section; should the system also push notifications to the user, perhaps with the recommendation actions?

One of the bigger insights drawn early in this thesis was that the visualization of data over a time period could be a tool for planning the usage so that peaks in consumption
could be simultaneous as the production peaks. The reason for doing so was to avoid surplus production and maximize the user’s self-sufficiency. When asking the customers about this in the interviews, the idea got positive reactions. But after the prototype iterations it did not seem like the customers actually want to do this – their way of approaching self-sufficiency seems to be accomplished using long-term analysis of their data, in contrast to using live data as a ground for that goal.

In the latest prototype iteration, external factors were taken into the data visualization – average outdoor temperature and solar irradiance. It is however important to notice that the chosen factors were arbitrary and the core of the idea lies in expanding the view for the customer in order to provide better ground for understanding and decision making. According to Umeå Energi, the solar irradiance data available is not usable in this context due to scattered measurements – both in terms of geographic location within Sweden as well as time (available data is far from live). If this area will be looked into any further, services as Watt-Sun \cite{52} may be of interest. It uses machine-learning to forecast solar data, instead of live measurements.

5.3 Conclusions

The conclusions drawn refer to Umeå Energi’s current solar panel customers and may differ to the coming customers adopting further on. This current customer group is however not completely homogeneous as discussed in section \cite{22} but the main conclusions below applies to them as a whole.

Why

The main reason for the customers of getting the information about electricity consumption and production is for them to be able to maximize the self-sufficiency, as well as to see how their behaviour instantaneously affects the outcome. Comparing their outcome to previous time periods are of interest, also with the goal of understanding the outcome of their behaviour. All understanding seems to serve as knowledge for reaching greater self-sufficiency. They also want to use it as a tool for showing friends and neighbours how the system is performing.

Where

The customers want to have access to the information on various places depending on the current reason for seeing it. Mainly in their homes for tracking progress, but also when away from home to show friends and family how the system is performing.

When

Both sparsely on monthly basis for drawing conclusions regarding consumption behaviour, and spontaneously to see how it is going and what outcome specific changes (i.e. turning on the vacuum cleaner or switching off lights) make.

Measuring unit
To be able to follow the consumption and production progress over a larger time scale, the kilowatt-hour (kWh) is a good choice of measuring unit. This is because it does not have to be adjusted due to pricing changes, inflation, taxes and such. Metaphors, such as cars taken off the road or the equivalent money saved, can be used as a complement on top of the kWh.

How

To accomplish the things mentioned above, a mobile app is a good choice since it can meet the demands mentioned above, and was also a popular suggestion from the customers when interviewing them. Specifically how the app should be offered (native app, web app etc.) is not looked into, but the customers themselves stated that a native app was their first choice. This should be investigated further prior to launching it.

5.4 Future Work

When using the results from this thesis it is important to understand the limitations that has been surrounding the work, which are discussed in section 1.1.3. The most important limitation to compensate for is probably the target group, understanding for whom the visualization is aimed at is key. Regarding the prototypes, the last two iterations should probably be the ones used as a ground for further development – keeping in mind that the last one not yet has been tested at all.

The work of this research has given insights into related topics that did not fit into the frame of the thesis. They may however be of interest despite that they are not looked into in any detail, and are briefly described below.

5.4.1 Investigation of early majority

Since the future customers of solar panels may differ from the current ones, it is probably of interest to investigate how the early majority differs from the current users that have been part of this research.

5.4.2 Prediction of solar production based on weather forecast

Is it possible to predict solar production based on short term weather forecasts?

5.4.3 Prediction of solar production and/or electricity consumption by data analysis

Can production and/or consumption be predicted by analyzing the production and consumption by nearby, or by other terms similar, customers?
5.4.4 Detection of snow on solar panels by data analysis

Can this be detected by comparing the current production with forecast and/or the production by nearby customers?
References


Visualization of electricity consumption and solar panel production for house owners

June 11, 2018


[29] “Exploring consumer preferences for home energy display functionality”. In: (2009).


[31] “Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms”. In: (2015).


[40] E.ON energy company. URL: https://www.eon.se/ (visited on 03/12/2018).
Visualization of electricity consumption and solar panel production for house owners

June 11, 2018


[42] Service Design. URL: http://www.inuse.se/hur/service-design/ (visited on 12/05/2017).


[51] Project Sunroof. URL: https://www.google.com/get/sunroof (visited on 03/21/2018).