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Evaluation of a Solar Map

Investing in Household PV from a Prosumer Standpoint

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Evaluation of a Solar Map

Investing in Household PV from a Prosumer Standpoint

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Preface

This thesis is the final degree project within the master's program Sustainable Energy Engineering at the KTH - Royal Institute of Technology. This study is a result from a research collaboration between KTH and Karlstads Energi which is funded by the Swedish Energy Agency through the Design for Energy Effective Lifestyles program (Project Number 48103–1).

I would very much like to acknowledge and give a great thank you to my KTH supervisor Nelson Sommerfeldt, postdoctoral Researcher at KTH, who has been a great support in completing this thesis as well as providing insights and knowledge in the field. I also want to thank David Bohn Stoltz, Business Developer at Karlstads Energi, without whom this thesis would not have been possible and for helping with the data collection.

Abstract

English

Investment in solar power is increasing in Sweden and especially the smaller installation below 20 kW which is typical for villa roofs. Potential prosumer can use a solar map, an interactive online tool, to investigate the solar potential of their roof based on a geographical data. A study analyzing several solar concludes that the results vary greatly depending on the tool and assumptions made by the provider. This thesis aims to determine the most effective online communication techniques for communicating the cost and benefit of solar PV to potential prosumers. The overall aim of effective communication is based on utility, framing, and trust. To achieve the aim semi-structured interviews and a technical verification of a solar map in Karlstad. The website of Karlstads Energi operates by asking the user to mark their roof area and enter their yearly electricity consumption.

The ability to effectively convey information that is useful, attractive, and trustworthy is based on the user. There is not one perfect design that will work for all users as the users have different knowledge and interests going in which varies the utility. The framing that is the most favorable is using the yearly production in kWh described as a financial investment focusing on savings from the system together with environmental aspects. Users base the trust of the results on more than the figures. Previous brand recognition as well as opinions from previous users weigh in when evaluating the results before decision making.

Key words

Solar map, prosumers, solar PV, consumer behavior, decision making

Svensk sammanfattning

Alternativ titel: Utvärdering av en Solkarta – Hushållsinvesteringar i solceller som prosument

Investering inom Solkraften ökar i Sverige, speciellt mindre installationer under 20 kW vilket är typiskt för villatak. Potentiella prosumenter kan använda en solkarta, ett interaktivt onlineverktyg, för att undersöka solpotentialen på sitt tak baserat på geografisk data. En studie som analyserade flera solkartor drar slutsatsen att resultaten varierar mycket beroende på verktyget och de antaganden som skaparen gjort. Detta examensarbete syftar till att fastställa de mest effektiva onlinekommunikationsteknikerna för att kommunicera kostnaden och nyttan av solenergi till potentiella prosumenter. Där effektiv kommunikation bygger på användbarhet, presentation och tillit. För att uppnå syftet genomförs semistrukturerade intervjuer och en teknisk verifiering av en solkarta i Karlstad. Karlstads Energis solkarta fungerar genom att be användaren att markera sin takyta och ange sin årliga elförbrukning.

Förmågan att effektivt förmedla information som är användbar, attraktiv och pålitlig baseras på användaren. Det finns inte en perfekt design som fungerar för alla användare eftersom användarna har olika kunskaper och intressen vilket påverkar användbarheten. Den presentationen som är mest fördelaktig är att använda årsproduktionen i kWh som beskrivs som en finansiell investering med fokus på besparingar från systemet tillsammans med miljöaspekter. Användare baserar förtroendet för resultaten på mer än siffrorna. Tidigare varumärkeskännedom samt åsikter från tidigare användare väger in när man utvärderar resultaten innan beslut fattas.

Nyckelord

Solkarta, prosument, solceller, konsumentbeteende, beslutsfattning

Nomenclature

Azimuth – Angle of building normal from south

Energimyndigheten - The Swedish Energy Agency

HOX – Homeowner identifier

IRR – Internal rate of return

Irradiance - Amount of light energy received by a surface per unit area

LoD – Level of detail

OM – Operations and maintenance

Payback time - Amount of time it takes for an investment to breakeven

Tilt angle - Angel of the roof compared to flat surface

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1 Introduction

The EU Commission has set a 2030 Climate Target Plan which aims to reduce at least 55% of the greenhouse gas emissions by 2030 compared to the levels of 1990. This was done to raise the ambitions and to help policymakers and investors make decisions not conflicting with the EU goal of being climate-neutral by 2050. The impact of this is hopefully new climate and energy proposals that will decarbonize the European economy. This is also in line with the Paris agreement objective to keep global warming below 2 degrees C and keep it at 1.5 degrees C(European Commission, n.d.-a).

The EU believes solar power can play a role in reaching the set targets and have the possibility of producing 20% of the electricity demand in 2040. In 2018 photovoltaics (PV) produced 127 TWh of electricity which is 3,9% of EU's gross electricity output. To make the 20% a reality EU funds research in photovoltaics, CSP and solar heating and cooling. For PV the research includes finding new materials, make better designs with a higher efficiency and lower the cost of generating electricity(European Commission, n.d.-b).

The current electricity mix in Sweden contains renewable energy from hydro, wind, solar power and bio as well as nuclear energy. The Swedish climate and energy targets contain a goal 100% renewable electricity production by 2040 (Energimyndigheten, 2020b). Solar power is increasing in Sweden and especially the smaller installation below 20 kW which is typical for villa roof installations. According to Energymyndigheten the installed capacity of smaller solar energy system has steadily increased in the last 5 years and in 2019 surpassed the medium size installations of 20 to 1000 kW (Energimyndigheten, 2020a).

If a villa owner today wants to invest in solar PV for their private home, there are a number of websites from companies selling PV systems available to calculate the size and yield from the system based on the data the customer provides. A study in 2021 analyzing several websites using the same building concludes that the results vary greatly depending on the tool and assumptions made by the provider that is hard to verify by the customer (Sommerfeldt et al., 2022). The results may also provide an overly optimistic results and with no certain tool from a "trusted" source to verify it with can affect the solar PV market and confuse the customers. The savings for example are based on the future electricity price and will therefor affect the payback time that customers use to determine whether to invest or not. This may erode the market as consumers may be overpromised on a system that may not preform to this standard and the data provided is not as certain as they are led to believe (Sommerfeldt et al., 2022).

These websites where potential prosumer may investigate the solar yield from their homes can be interactive tools that can provide information of the solar potential of a roof based on a geographical data in a map, this is called a solar map. These maps usually come from PV sellers, commercial third parties or government. There are different types of maps where you input varying data as well as marking the area in question, the three main types are manual input, solar map or a hybrid of both. A manual input will ask the users to enter certain values of the intended area such as tilt, orientation, available area etc. to get the results from a suggested system(Svensk Solenergi, n.d.). Solar maps are based on geographical information where the irradiance is based on 3D models of the area which can be used to get the results from a PV system. Hybrids are the most common maps where the user both mark the area on a map/satellite image as well as adding information on the house and/or demand for techno-economical calculations (Sommerfeldt et al., 2022).

1.1 Level of detail

Level of detail (LoD) is a concept used in 3D city modeling amongst other disciplines. It defines the amount of detail from real world objects in a 3D-model. The 3D-model can be used to assessing solar potential by estimating the direction, tilt and area of the roof to get a potential yield from solar panels on the roof. Since panels are only placed on roof areas without obstacles as windows or such this requires LoD with fine roof structure. Other things such as vegetation that may shade the panels are also of importance but will again require a higher LoD. There is no one standard for the LoD but CityGML defines a standard of five LoDs, LOD0-LOD4. LOD0 is just for areas that does not contain volume such as regional or landscape areas. LOD1 is a block model with a flat roof structure, LOD2 has differentiated roof structures and boundary surfaces. LOD3 has detailed wall and roof structures with doors and windows and LOD4 has the same exterior as LOD3 but also includes interior surfaces such as rooms, stairs and so forth. The different LoD can be described as in Figure 1.1 and it’s the definition that will be used in this study as there is not a set definition for LOD in 3D city modelling(Biljecki F, 2013).

$$\xrightarrow{\text{Footprint}} 0 \xrightarrow{\text{Block model}} 1 \xrightarrow{\text{Coarse exterior}} 2 \xrightarrow{\text{Fine exterior}} 3 \xrightarrow{\text{Interior}} 4$$

Figure 1.1 LoD levels from CityGML based on (Biljecki F, 2013)

How solar maps are build are for the most part by using LiDAR, light detection and ranging, for models of urban areas. The laser scanning is done by sending laser light towards the surface and compiling and analyzing the reflected signals. This can detect vegetation from buildings but one limitation is that the facade details cannot be properly modeled later from the data. The data gathering using LiDAR can take up to a few years based on the size of the area that is being mapped. The model is then generated from the data by reconstructing the buildings by using a software that will produce a 3D-mesh. The mesh will be blurry from the LiDAR data, the geometry will therefor need to be cleaned up to increase the accuracy of the model so that the detail needed for solar PV modeling can be performed. A coordinate system is added so that a given point in the map will have data of the tilt and direction. The solar irradiation is also calculated for that point and added to the map. When combining these aspects an annual yield map can be rendered of the building and the accuracy will depend on the LoD. If chimneys and such are excluded this can then affect the accuracy of the PV production as an overestimation may occur when areas that are not feasible is selected by the model due to the data being incomplete so that shading cannot be taken into account (Zhou et al., 2022).

1.2 Investing in solar PV

Based on Palm's study (2018), customers choosing a solar system for their home are more focused on the economic viability of the system and want to make a profit from the investment in 2014-2016 compared to 2008-2009 when the environmental factor was the greatest incentive. The market has also evolved and matured, for example it was not possible to be a prosumer in the first study and therefore not being able to sell excess to the grid (Palm, 2018). Consumers also understand and see information provided by the solar companies differently based on their background and interest in the industry. The data provided by companies may not always be to the consumers liking and may not be understandable without previous knowledge in engineering of the industry. This may deter customers from following thru on a purchase (Palm & Eriksson, 2018).

A study made in 2020 by Falkenström and Johansen investigated how micro producers in Sweden purchase solar PV and how the decision process is made and the timeline of it. The purchasing factors were based in quality, price, trust and brand recognition where quality was important and price was less of a deciding factor. There is usually not one reason that leads to a purchase but a combination of several. The primary reason for investing was the environment but also that the technology was mature enough.

A purchase is based on the trust in the product which also affects the expectation of the system. If the product does not preform according to the expectations there is a risk that the customer may not be satisfied even if it matches the original need. This is also why it is important to not oversell the product and get dissatisfied customers who otherwise would have been satisfied with the product (Falkenström & Johansen, 2020). The potential issue of low-quality information regarding the performance of solar systems to consumers is also discussed in Sommerfeldt et.al (2022).

In Falkenström and Johansen (2020), the respondents stated that the majority started looking for information within about six months after the initial thought of getting PV panels and they contacted a provider within six months of the initial search. This is more time than average on this purchase where more information makes the respondents feel more reassured about their purchase and they were more likely to choose a company they trusted or knew about beforehand. The information was found from providers or independent sources such as Energimyndigheten. Most of the participants only contacted one provider to get an offer, but participants with higher education were more likely to use more sources than participants with a lower education. When asked what information they were missing in the process they stated that information about the economical calculations such as optimal size of the system, performance of the system and information about subsidies and contributions for the system. About the process they were missing information about the expected timeline as well as what party is in charge of each step. Information about the product that was missing was partly the esthetic part of the system and how it operated during a grid outage or a thunderstorm for example (Falkenström & Johansen, 2020).

Expanding from Sommerfeldt et al. (2022), a collaboration with Karlstads Energi aims to examine information delivery further. Their website, which already had a solar map for potential customers, was expanded to four versions and consumers were assigned one at random to see what presentation of data were favored. The data logged from this has previously not reached a statistically significance due to low usage and not provided a definitive result. The thought process and how much the users understand cannot be found from this data and this is what this report aims to understand.

1.3 Aim

This thesis aims to determine the most effective online communication techniques for communicating the cost and benefit of solar PV to potential prosumers. An effective communication strategy provides an honest representation of the PV system that the user fully understands and enables informed decision making. The communication is also effective in nudging the potential prosumer in continuing the process towards getting a PV system, while at the same time not providing overly optimistic results which are unlikely to occur when the system is operating.

The overall aim of effective communication consists of multiple sub-objectives around three themes – utility, framing, and trust:

- Identify the ability for online tools to convey useful information, including uncertainties about the future (utility).
- Identify if the framing of techno-economic information influences how the potential prosumer perceives attractiveness of the PV system (framing).
- Convey confidence to the potential prosumer that the information is trustworthy and complete(trust).

2 Method

To achieve the aim of the study and the sub objectives, semi-structured interviews (SSI) and a technical verification of the solar map in Karlstads by using SAM is performed. Semi-structured interviews are performed with potential investors who have used Karlstads Energis webpage. During the interview the website is used and the questions in the interview follow the structure of utility, framing and trust to achieve the aim of the study. Due to the structure of SSI with the ability to ask follow up questions, there is a possibility to get further information about their understanding of the information, what version they prefer and key figures they are looking for together with the decision process for them. The technical verification is made to compare the results from the website of each building with simulations from SAM and the sizing of the system to see if the website is able to produce an accurate system.

2.1 Karlstads Energis solar map

The website of Karlstads Energi operates by asking the potential prosumer to find their house on a map by either zooming in or enter their address and then marking the area in which they are interested in installing solar PV. Then the yearly electricity consumption is asked by either steps of 500 kWh or by writing the amount. The website operates with four different version since November 2nd 2021 with some updates to the sign-up form in early December 2021. The four different versions are randomly assigned to potential prosumers. The results are the same for the same building and consumption and the graphics used are all the same, but the difference in comes from the wording of the descriptions and what economic results are highlighted. The versions are Original, Monthly, Investment and Savings. Original version which presents the results on a yearly basis with focus on payback time, the Monthly version which is described the same as Original but divided into monthly results, Investment presents yearly results but described as an investment/gain with focus on profit in percent (IRR) and Savings presents yearly results as savings with emphasis in savings over the entire lifetime. The different versions are visually presented in the Figure 2.1 in Swedish(Karlstads Energi, n.d.).

Figure 2.1 The different versions of the website

This solar map is currently only operating in the municipality of Karlstad. The data in the map from central Karlstad are based on a 3D-model from 2015 and for areas in nearby villages and countryside the map is based on an older laser scan which affects the LoD of the map. The map takes shadowing from other buildings into consideration when modeling but not possible shade from vegetation. Users are advised that a shadowing tree for example can reduce the production. The irradiation is based on the location of the roof with data from SMHI and will vary for each house, so no exact azimuth or tilt is specified in the map but comes from the 3D-model or the older laser scans(Karlstads Energi, n.d.). Self-consumption is calculated based on the individual demand and production and an example of the distribution per month can be seen in Figure 2.2.

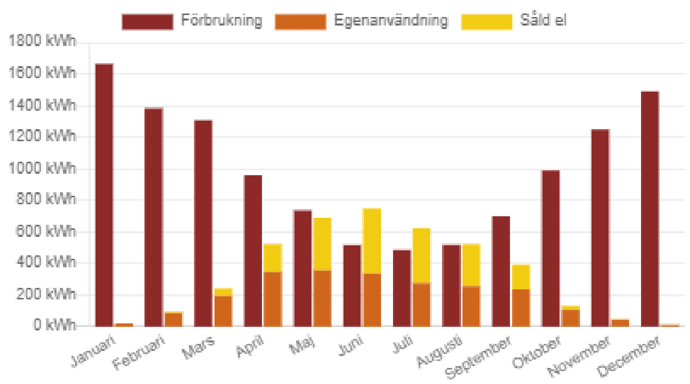


Figure 2.2 Assumed distribution of demand and production

The website is designed to work both in a mobile and from a computer. The optimized system is therefore placed like a column where everything is just below each other. The results are presented as overall system, economic results, environmental results, and a calculator. In each of these topics the user may expand the results by pressing *show more* to get further information about the results. When the calculator is expanded you get the view of Figure 2.3, here the user can alter their demand, the size of the system, electricity price and price change per year and lifetime of the system. The yearly production in kWh/kW which is dependent on the location of the selected area and the investment cost per kW including taxes is also presented and can be altered be un-checking the assumed values. Any alterations will re-calculate the results which will change in the first image of the website as well as in the information under each topic. This is the function on the website that will be referred to as the calculator throughout the paper.

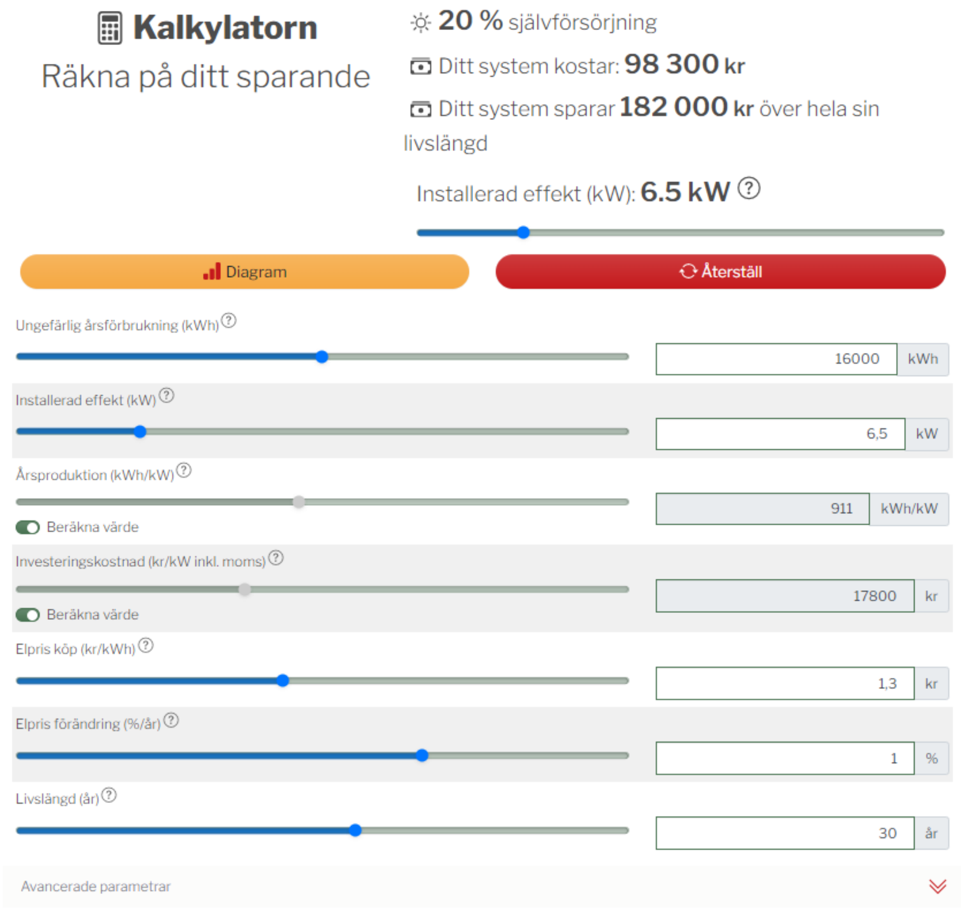


Figure 2.3 Calculator view on the website

The map operates with the assumption that maximum 80% of the roof area can be used for panel fitting to account for chimneys and such. The recommended system presented is the one with the shortest payback time not the largest system that can fit the area, the user is informed that a system on a villa is usually 3-10 kW. The panel efficiency is assumed to be 20% with PV degradation 0,3% per year and the panels area assumed to be 1x1.7 m in size. The system is calculated using a lifetime of 30 years but it is stated that the lifetime can be shorter if the components is of subpar quality. The operation and maintenance is assumed to be 1% of the installation price and this includes a change on inverter after 15 years. Under advanced parameters more of the economic factors that goes into the calculator can be found and altered by the user as seen in Figure 2.4. The buying price for electricity is assumed to be 1,3 kr/kWh which includes both the electricity supplier and electricity network owner, the price is assumed to increase by 1% per year. The selling price of the over production is assumed to be 0,3 kr/kWh, 0.06 kr/kWh for electricity certification during 15 years and 0.6 kr/kWh in tax reduction for 10 years. The installation cost is 17 800 kr/kW including taxes with 15% investment support. This price is based on data from suppliers and statistics from Energimyndigheten and is stated that the price can vary +/-20% depending on the materials, type of roof and installer (Karlstads Energi, n.d.).

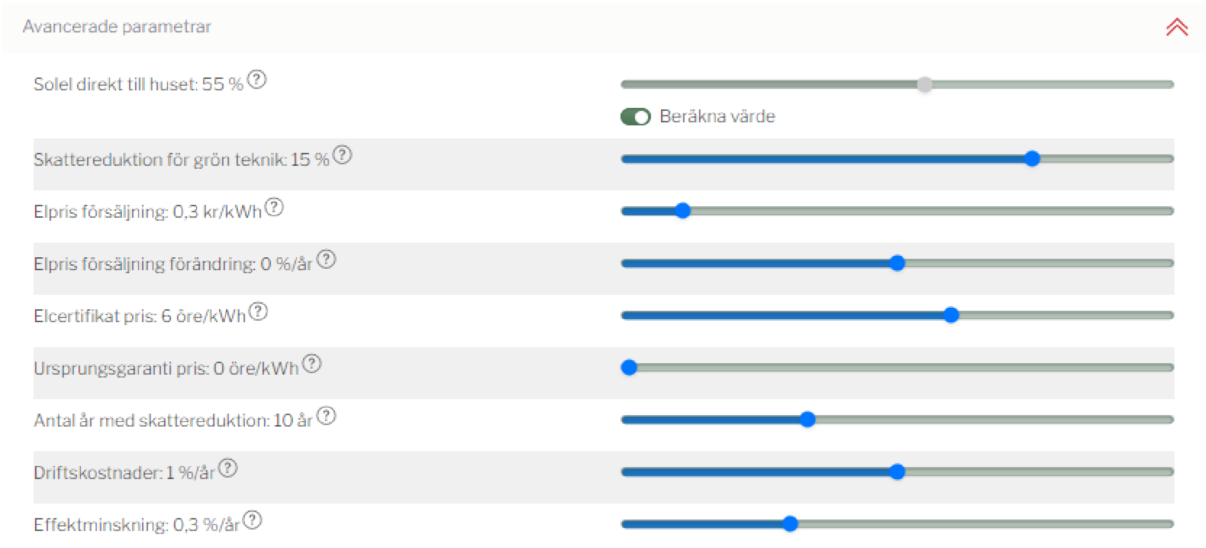


Figure 2.4 Advanced parameters in the calculator

The websites log the clicks from visitors and when a potential prosumer have used the website and filled out the interest form the data from the website is mapped to them. This is to get an idea how the website is used and what areas each visitor have an interest in and investigated more.

2.2 Technical verification of system

As Sommerfeldt et al. (2022) discover that the simulation done on websites with solar maps varies greatly and may produce overly positive results. To verify the website and compare the results to reality each of the houses in the study will get a simulated system by using SAM. This is also to see what assumption in the website calculations should be altered to better match reality.

SAM which stands for System Advisor Model is a free software where photovoltaic systems can be designed for a techno-economic evaluation amongst other renewable energy technologies. In SAM, panels and inverters can be selected to design a system which is then operated using a weather file which is provided by the user to get the results of the system. For this project, SAM was only used for technical evaluations(National Renewable Energy Laboratory, n.d.).

The area each of the rooftops in the study is measured and the azimuth and tilt are either based on data offered by the participants in the interview, estimated from the satellite image or found using street view when available. When street view was not available the angle was estimated which may affect the production of the system. A 10 degree error in the tilt can affect the production with about 2-6% unit of percent with the tilt angles used in this report(Solcellskollen, 2022), this can be a source of error of the results. A SAM parameterization is made for a model of panel similar to what is used by the current contractor of Karlstads Energi and of the similar size and capacity used on the webpage. The parametrization used was a tilt of 20-45 degrees and azimuth of 100 degrees east to 90 degrees west based on the roofs in the study. The SAM results are collected in kWh/kW, this is then multiplied with the number of panels and the panel capacity to get the results in kWh to compare with the website. As the website does not recommend a specific panel but a total capacity and a number of panels the average panel capacity from that was a used. The panel used was 1x1,7 m and of a capacity 325 W and has an efficiency of 20%, this was paired with a microinverter to get the results.

The area of roof is found using the measurement tool at *Min karta* on Lantmäteriets webpage(Lantmäteriet, n.d.). The total available area is used even if the placement might be shadowed by a chimney, windows or such to be able to compare with the website optimum and maximum amount of panels. For example in Figure 2.5 there is a chimney which is not seen as available area and limits the number of panels possible which will also shade any panels placed north-west of the chimney. In the available area the panels are tested both in landscape and portrait mode to see which placement will result in the largest number of panels.

Figure 2.5 Example of roof measurement and information gathering

Since the area is measured from a satellite image some the area is not correctly represented due to the slope of the roof as can be seen in Figure 2.6. The area is calculated before the panels are placed onto it by using equation 1.

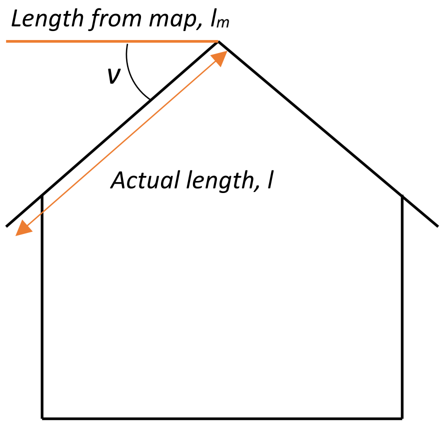


Figure 2.6 Calculation of roof area

$$Actual\ length, l = \frac{l_m}{\cos v} \quad (1)$$

2.3 Semi-structured interviews

To achieve the aim and sub-objectives Semi-structured interviews (SSI) are chosen as the method to be able to get the participants to go through how they use the website and their opinion of the functions and data they are presented with. The ability to ask follow up questions from base questions to be able to find the independent thoughts is one of the strengths of semi-structured interviews. An SSI is flexible and does not follow a script strictly. It is however important to have a structure to the interview with an agenda that is altered to the different groups that may participate. The areas covered in the interview was based on the sub-objectives of utility, framing and trust. Utility meaning using of the website and what tools are available, framing is how the information is presented and if it is understandable to the user and trust is the trustworthiness of the information and website perceived by the user. SSI in comparison to group interviews can also be used when the topic is considered sensitive by the participants and who may not be comfortable with discussing in front of others. It can however be time consuming, and a statistical analysis cannot be performed from the sample size (Adams, 2015).

The interviewees asked to participate in the study were found via Karlstads Energi. To be asked to participate they will have used the solar maps on the website and then proceeded to sign up their interest in getting solar PV for their house. These subjects received a targeted email to ask them to participate in this study during the spring and were given a coupon to a local business as an incentive. The email was followed up by a text message after one week to increase the participation. The interviews are performed over Zoom one-on-one with the participants, this will make the recording of the interviews easier and can then be performed at a time of convenience of the respondent. They were asked to use a computer for the interview to interact with the webpage, this was done by 12 of the participants and two used a tablet instead.

The expected time of the interviews was stated in the email to 30-40 minutes. To not fatigue the interviewer and to not inconvenience the interviewee, it is recommended to stay blow on hour. A too long stated time can result in less willing participants and an unrealistically short may result in them leaving early with important aspects still missing. Under estimation the time can also cause the subjects to feel deceived and loose respect for the interviewer. Should the interview run too long it is good to get consent for continuing with asking "if they are okay with only a few more questions"(Adams, 2015). A pilot to test the questions, the time management and a technical check of Zoom with similar subject was performed before the actual interviews.

The questions should try to use everyday language in the native tongue of the participants and not talk down to them by using too technical terms to promote easier communication. Acronyms and terms that may not be known to the participant should be avoided. The wording of the questions should be carefully considered for optimal results. It is good to start the interview with easier, less important questions to get the conversation going and the participants more comfortable. Psychologically is it good to ask for positive opinions first because after negative feedback the tone may have shifted, and they can be more reluctant to give praise as to not contradict themselves (Adams, 2015).

2.3.1 Structure of the interviews

The study is briefly introduced to the participants and consent to record is asked before the interview begins. As the interview is done digitally they will have to consent on their screens to the recording. The respondent is asked why they are interested in getting solar PV for their home to get some initial information for their reason and thought of a potential system. The respondent is then asked to use the original website and to explain their thought process while doing so. This is to see which areas they choose to look more into and what areas might affect their opinion on the investment and what areas they might ignore or not understand. Then each of the versions are presented side by side using images with results similar to the previously presented result based on their usage of the website, to see if any specific wording or figure is particularly appealing to them. The interview then continues with the questions in Table 2.1, the questions in Swedish can be found in appendix A. The interview questions are placed at the end to not influence the participants and their thought process and opinion of the website. Demographics are asked at the end of the interview because it might be seen as sensitive information. Refusal to give information in sensitive topics can be minimized by asking them to choose from a broad spectrum for example income. In this study the participants are asked about gender, age, education level and income in brackets of 10 000 SEK.

Table 2.1 Parts of interview compared to the aim

Interview parts	Utility	Framing	Trust
Using the webpage	X		
Different versions of webpage		X	
Q1. What information that convinced you to continue with the interest form?		X	X
Q2. Did you get the information you need to make an informed decision?		X	X
Q3. Is there a graph, data or feature that you are missing from the website?	X	X	
Q4. Did the information provided help your understanding of the system and the investment?		X	X
Q5. Do you think about how the performance could be different from expectations?	X		
Q6. Were the features of the website useful towards your understanding of the system?	X		X
Q7. How credible did you perceive the website and results?			X
Q8. Did you compare the results with any other provider or independent source?			X
Q9. Does anything else influence your decision?			

2.3.2 Subjects of the interview

The interviews were conducted with 14 participants ranging from the ages of 36-80 this can be seen in Figure 2.7. In the group, four identifies as women and 10 as men. The monthly income ranged from 20-30 to 70-80 thousand SEK with a median of 40 thousand SEK this is shown in Figure 2.7. The education level of the participants was from Swedish gymnasium level to Master of Science as is shown in Figure 2.9. There were three participants who are working or have education in energy and three others who have a technical further education. The occupation fields varied between energy, HR, IT, engineering, pharmacy, dentistry and education. The education level does not equalize knowledge of the market or system, instead the knowledge was gained from interest in the solar market. Continuously the participants will be referred to as HOX which stands for homeowners and a number to keep them anonymous throughout the thesis.

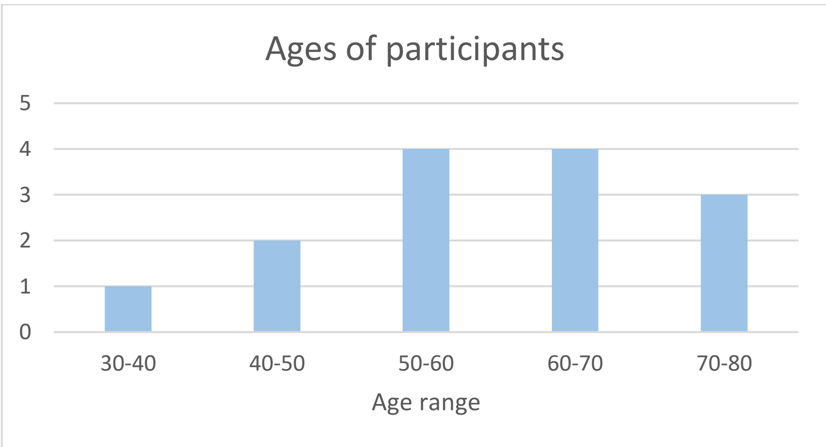


Figure 2.7 Ages of participants

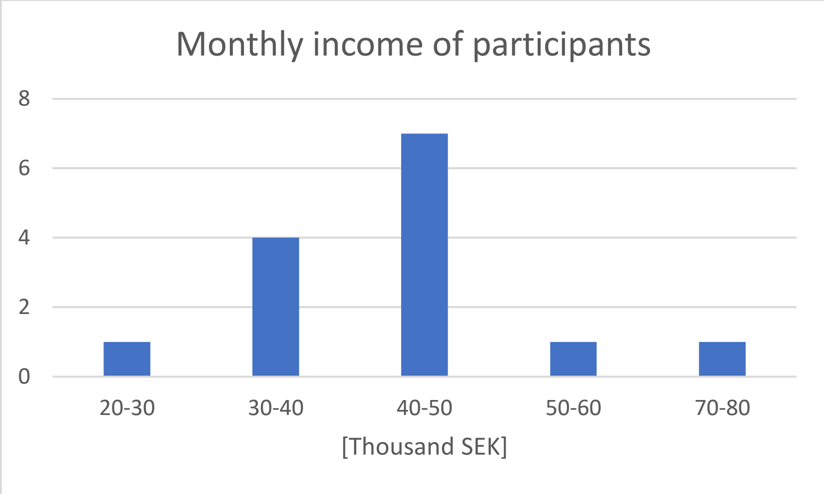


Figure 2.8 Monthly income of participants

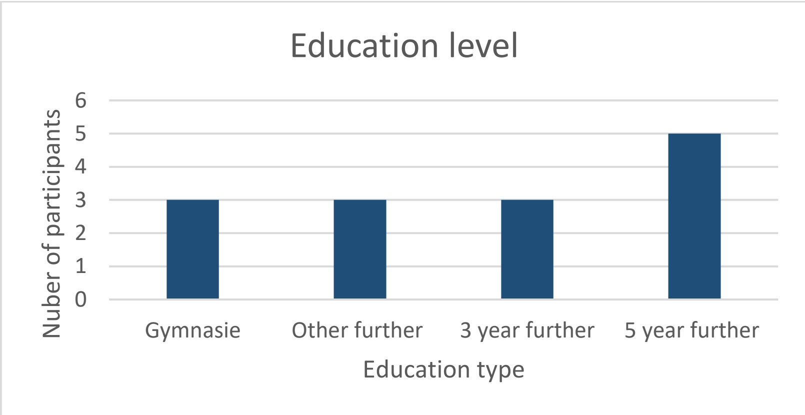


Figure 2.9 Education level

Of the participants three have already placed orders from other companies after taking in offers from several companies. Three already have a solar PV system on the same or other properties, had a good experience, and is therefore looking into investing in more. There were four who were absolutely sure they would invest this year at some point they were just waiting for the offers to make a decision. And the last four had as one person put it “just gotten the ball rolling”, they were positive to an investment but hade so far only used the website and not really looked any further for companies or other information.

The study groups demographics is not representative for the Swedish population, but the group is comparable to other studies such as (Sommerfeldt et al., 2022), (Palm & Eriksson, 2018), (Falkenström & Johansen, 2020) and (Palm, 2018).

2.4 Limitations of the study

This study was conducted during an exceptional time in the spring of 2022 with high electricity prices during the winter and the war breaking out in Ukraine. The price for electricity the winter 2021 to -22 were record high. The average yearly price in 2021 on the Nord Pool Spot Market was 554% higher than in 2020 with the highest hourly prices in December 2021(Rydegran, 2021).

February 24 Russia launches a military offensive in Ukraine and the area was declared an active conflict zone. The consequences of the war in Ukraine on the solar market is that the materials that is needed for the production of PV panels are not being mined or exported(Ecokraft, n.d.). This is causing a delay of production during a high demand period as the spring normally is and companies are struggling with delivering systems to customers. The war may also affect why an investment in solar PV is made compared to previous reasons.

Unfortunately only 14 persons were reached with the channels used which is quite a small sample size which limits the possibility to draw any generalized and definitive conclusions from this study.

3 Results

The results from the map usage, solar calculations and the interviews will be presented in this chapter.

3.1 Solar map technical results

The results from the solar map compared to the interviews and calculation from SAM is found in Table 3.1. The demand entered when using the site at home was not consistent with the use during the interview. Some of the participants were unsure of their demand and did not have the data available for the interview and were therefore asked to estimate with guidance. Any sizing effect of demand change is shown in Table 3.1.

The different demands vary with habits and conditions of the house such as heating type and insulation. Three participants mentioned having electric radiators as heating and two having electric radiator in combination with air source heat pumps. Currently three of the participants owns a hybrid vehicle and seven are considering getting one in the future. Two of the participants deliberately input a higher demand from their current usage because they predict higher demands in the future from change in habit or getting an electric vehicle.

The yearly production from solar map vs what is calculated using SAM is quite similar. With the same amount of panels the yearly production from SAM varies from 90% to 105% of the results from the map with the average being 99,86%. The max amount of panels had results varying of 60% to 300 % of the recommended size, the average was 146,5% compare to the website results. The SAM output used for the results can be found in Appendix B.

Table 3.1 Results from the solar map

HOX	**Use of Solar Map at home**						**Use in interview**			**Simulated system**		
	Demand [kWh]	Optimal number of panels	Optimal system size [kW]	Yearly production [kWh]	Max number of panels	Max system size [kW]	Demand [kWh]	Optimal number of panels	Yearly production [kWh]	Max number of panels calculated	Yearly production from optimal number of panels [kWh]	Yearly production from calculated number of panels [kWh]
HO1	12 500	20	6,5	5900	40	12	13 500	20	5900	22[3]	5785	6364
HO2	16 000	20	6,5	5920	71	22	19 500	20	5920	41[3]	5346	10329
HO3	18 000	18	6	4470	40	12,5	18800	18	4470	56	4038	13447
HO4	20 000	20	6,5	5270	78[2]	39	15 000	20	5270	22[3]	5293	5822
HO5	7 500	14	4,5	4130	28	6	6 500	17	5040	12	3831	3284
HO6	14 500	17	5,5	5120	35	11,5	15 500	17	5120	20	4929	5798
HO7	17 000	20	6,5	5190	78[2]	33	20 000	20	5190	34[3]	5315	9036
HO8	28 000	23	7,5	6620	78[2]	39,5	23 500	20	5740	70[3]	6201	16439
HO9	12 000[1]	20	6,5	5280	70	22,5	18 000	18	4870	35	5395	8631
HO10	9 000	17	5,5	3670	40	13	9500	20	4340	24	4590	6481
HO11	25 000	20	6,5	5430	50	16	26 000	20	5430	32[3]	5487	8779
HO12	12 000[1]	15	5	4050	12	4	10 000	15	4050	10	3970	2646
HO13	12 000[1]	17	5,5	3930	29	9,5	17 000	20	4620	20	3994	4438
HO14	5700	17	5,5	4520	40	13	5700	17	4520	12	4785	2815

[1] Default setting in the solar map.

[2] The website won't allow a system larger than 25 kW and it therefore capping out at 78 panels.

[3] Includes panels in a non-optimal placement with regards to shadowing from example chimneys or roof nooks.

Sizing errors from the solar map in Table 3.1 can be found in row HO5, HO9 and HO12. The errors are found when comparing the columns optimal system size and max system size as well as in the number of panels from home use compared to in the interview. In HO5 and HO9 the map recommends a larger system to a smaller demand and for HO5 the recommended size is larger than the max size. This is also visible in Figure 3.1 where the max number of panels is below the optimal number of panels.

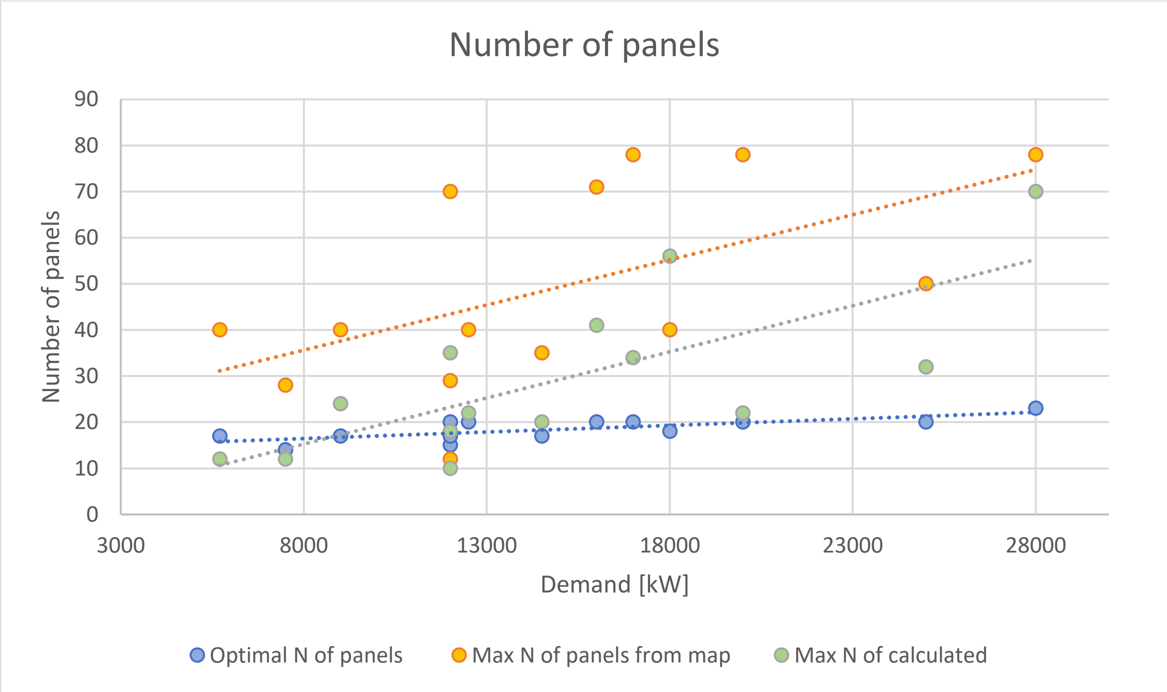


Figure 3.1 Number of panels

The map seems to have an optimum at around 20 panels, equivalent of 6,5 kW_p, as the demand varies but number of panels remain similar as can be seen in Figure 3.1. However the maximal amount of panels from the map compared to the calculated varies as the map only takes area into consideration is not consistent. The map in general overestimates the area that is available on the roofs. Of the areas selected by the participants eight had chimneys or dormers that limited the available area which was not visible on the map due to the LoD. On average the max number of panels according to the map is double the amount calculated, and in only one case did the map underestimate the max number of panels.

3.1.1 Website usage

Data logged from when the participants used the website and signed up on the interest form for solar PV is presented in Table 3.2. How the website is used is of value to the utility and framing of the website. If the users are not utilizing the available functions the design might need to be altered to better match what user have described that they are looking for during the interviews. Of the data available five used a phone to access the solar map, six used a computer and two used a tablet. The website interaction in the table signifies the clicks made and tools used when on the website. With little input they did not do any other clicks than selected their roof, entered a demand and continued with the interest form. Some usage refers to doing more clicks of either expanding the economy or environmental information, looked at the tool tips in the first diagram or downloaded the results. With little interaction the average time was about 4 minutes, with some usage the average time was about 15,5 minutes and more usage including the calculator the average was 21 minutes.

Table 3.2 Data from solar map usage

HOX	Device used	Time spent	Website interaction
HO1	Computer	5 min	little
HO2	Phone	12 min	some
HO3	Phone	5 min	little
HO4	Phone	15 min	some
HO5	Phone	23 min	A lot, size changes and used calculator
HO6	Phone	4 min	little
HO7	Computer	20 min	Opened calculator, some changes
HO8	Not available	Not available	Not available
HO9	Computer	3 min	little
HO10	Computer	4 min	little
HO11	Tablet	15 min	Some
HO12	Computer	3 min	little
HO13	Computer	20 min	Some
HO14	Tablet	20 min	Opened calculator, looked at some sizes

3.2 Interview results

Here the results from the interviews will be presented in order of the interview.

3.2.1 Reason to invest

The reason of investing in solar PV varied within the group several mentioned that this is something that have been on their minds for some time and then recently gotten the push from the high electricity prices during the 2021-2022 winter, the current situation in Ukraine, contributing to the energy situation in Sweden or environmental factors to take the next step. Usually more than one reason was mentioned and economics and the environment were the most common in varying combinations. Five said that their primary reason was the high electricity prices, three were broader and mentioned their goal was to reduce their energy costs, three had the environment and higher self-sufficiency as a motive and interest in the technology was the motive for three. This is shown in figure 3.2. The most common secondary reason was the environmental factor which was expressed by 50% of the participants.

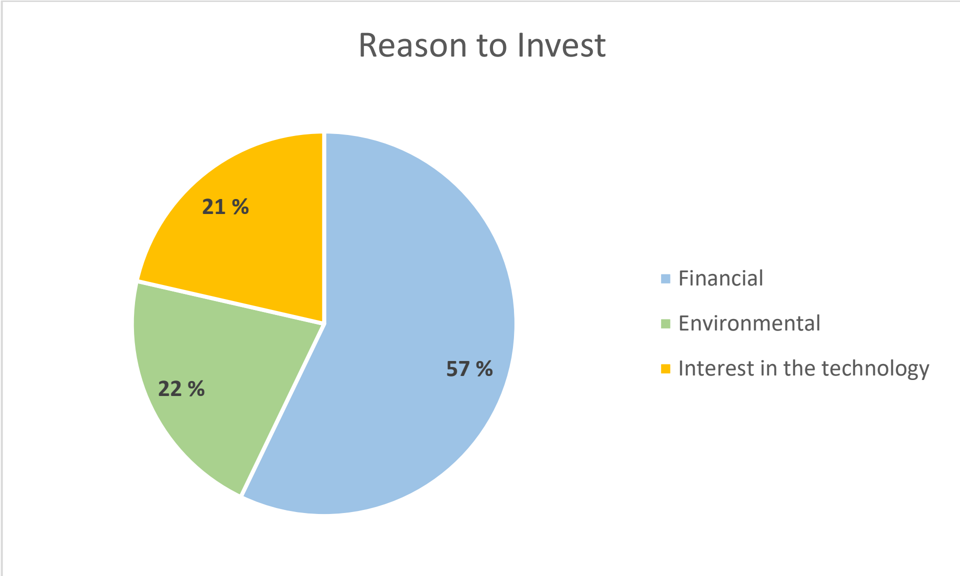


Figure 3.2 Reason to invest

No one believed this to be a “bad” investment as in they would lose money on it, two were happy breaking even on it while others believed that it will be paid back well within the lifetime. HO7 put it *“I won’t be losing money, I will be getting extra electricity and from an environmental standpoint we have a large roof, so I can do it and I can afford to do it*”. HO6 stated “*I knew that it would eventually pay off, I am only looking at what I can produce electricity wise*”. Ten of the participants believed that the electricity prices would continue to increase or not get lower in the future. They thought this would then reduce the payback time of the system and further benefit them.

The most important figure was the production in kWh that was compared to their demand which most found to be a tangible comparison instead of payback time as some were unfamiliar with the concept. Some thought the payback time was the time they would have to pay of the investment price with a loan. The production was also directly compared to their demand without taking the amount that is sold into consideration, they saw the total production amount as energy they will save. HO6 said “*how many kWh per year we would produce, that is what matters*”.

The investment cost vs the production was also compared (an indirect payback time) and they were usually looking to invest around 100 000 SEK, some wanted the largest possible while others wanted to be more cautious and start small to later increase. Five mentioned that they believed it will increase the value of their house in a possible sale, so even if they won’t receive the direct benefit from the investment this will be reimbursed by increasing the selling price. HO5 stated “*I think the electricity price will be high even in the summer if we are to electrify the society in the extent that they are talking about”*.

Knowing others who had a system was also mentioned as a factor and their experience and advice was appreciated. Some had also sought out forums on social media to get insight in the problem that might occur and what to consider before installing.

3.2.2 Solar Map version

In the interviews when shown the different versions of the solar map the participants found them too similar as the differences are not huge. But when pressed on any they liked more or less of the results presented per year were favored compared to monthly results as is shown in Table 3.3. This is because the monthly results were perceived as small in comparison to the investment cost and misleading as the monthly value will vary over the year. As HO12 described it "*well it's a little abstract to buy for 80 000 SEK and then only save 388 SEK, I think you mix the units too forcefully, because this is more of an investment and then you want to know the bigger picture".* The person who preferred the monthly wanted to be able to compare their monthly demand to the production when the system is installed and operating. Others also mentioned looking forward to this this technical aspect of "being nerdy" and seeing the production from their own systems day-by-day or monthly.

Table 3.3 Map usage and preference

HOX	Lod	Payback time from map [Years]	Self-sufficiency from map [%]	Investment cost [SEK]	Map randomly assigned	Map preferred in the interview	Map least preferred in the interview
HO1	2	17,1	23	98 300	Savings	Original and Savings	-
HO2	2	16	20	98 300	Savings	Investment	Monthly
HO3	1	19,1	17	92 800	Investment	Original	-
HO4	2	17,1	17	98 300	Investment	Savings	-
HO5	2	19,5	28	74 200	Savings	Savings	Monthly
HO6	2	16,2	20	86 500	Savings	Savings	Monthly
HO7	1	18	19	98 300	Monthly	Savings	Monthly
HO8	2	14,6	17	110 000	Investment	Savings	-
HO9	1	19,3	22	98 300	Original	Savings	-
HO10	1	25,5	21	86 500	Investment	Original	Monthly
HO11	2	15,8	16	98 300	Original	Even between the others	Monthly
HO12	2	19,9	19	80 800	Investment	Original	Monthly
HO13	2	22,1	19	86 500	Savings	-	-
HO14	1	23	30	86 500	Original	Monthly	Investment

What they preferred from the map varied with what they were looking for. Savings were popular because it states savings from the system over the lifetime compared to the payback time (original) or the profit in % (investment). Original was popular partly because the wording combines savings and investment and has less text making it seem cleaner as well as it presents payback time. Seeing the profit in percent were for the most part not appreciated, as HO12 stated "*I usually get a better return on the stock market than 3,31%,* *that's quite bad, I think I prefer original then".* The most important number that was expressed by 10 of the participants was the production in kWh compared to their demand and/or investment cost. HO3 said *"of course I look at the payback time, and I look at the self-sufficiency but perhaps not in % but in kWh instead".*

Some already had an aim for the production in mind that they wanted to achieve beforehand and what they considered would justify the investment. HO1 described it as *"I wanted to get about half of my demand and that is what I get with this system, that is what is interesting to me, if I get half of what I use I am pleased". HO12 said "if it had been 80 000 and only produce 2 000 kWh than maybe I would have told the kids to turn the lights of instead, but this seems doable".*

The preference of the amount if information that was provided on the website dependent on the knowledge and interest of the person. For example, HO5 stated "*I am that kind of person who likes information, rather I get to much information and can decide for myself, and I like the details"*. Meanwhile HO3 found it instead to be too much "*I think all of these percentages is too many numbers to keep track of, I want to know the cost for the investment, payback time and how much I will be producing"*. Within this lies the difficulty to design maps that will cater to the variety of homeowners that will use the website. The amount of data presented can make some uneasy while others more confident in the results.

3.2.3 Proceeded with the interest form

The reasons used to describe why they continued with the interest form from the results of the website was amongst others; easy, reasonable, doable, comparable, clear, price, electricity produced and Karlstads Energi. Getting solar PV for their home was usually something they had considered for a while but recently decided to act upon and discover further. Using Karlstads Energi's website was either from searching on the internet, having seen promotion for solar PV from Karlstads Energi or knowing others who had used them previously. In the interview the website was often compared to other similar tools and was considered easy to use in comparison. Easy in terms of easy access, you can do it from your own home and don't have to contact a company at a set time and you get a comparable result instantly, and the user interface was easy to use and understand**.** HO12 "*it was the simplicity in continuing with the interest form, it's free and you just send it in, no need for further contact, no chasing of any contractors, and we know others who have used Karlstads Energi so it feels reassuring*". HO5 said "*I like the color scheme and the interface, it is easy to understand, it feels doable, the simplicity of it"*. The results presented were also a part in why they proceeded with the interest form, they were mostly looking to find values for the price and electricity production to see if they found the investment worth continuing with or they continued because they wanted to get a personal offer to compare with other companies. Four of the participants had already decided to invest and just needed the verification of the results, two others also found the results reasonable or within their expectation. The results were then described as reasonable, doable, comparable and clear. Karlstads Energi as the sender gave reassurance and was seen as comparable with other offers. HO7 stated "*it seems doable, I suppose that is the purpose, to get people interested in and explain something you don't really know about in an easy way".*

3.2.4 Information from the website

When asked about the information they received about the system, some stated that they were still waiting for an offer and did not see the website as information they had received. Some did not consider the results as an actual system as it was not accurate enough but instead as a more general estimation of a possible system to work on further.

Another comment on the map was the different color of each roof, there is no legend or description of the chosen colors. They represent the suitability of the area. Sometimes houses which were in the same location were not valued with the same suitability, in Figure 3.3 the reason might be because the solar map considers the shading from other houses when calculating the results. This can affect how the users view the results.

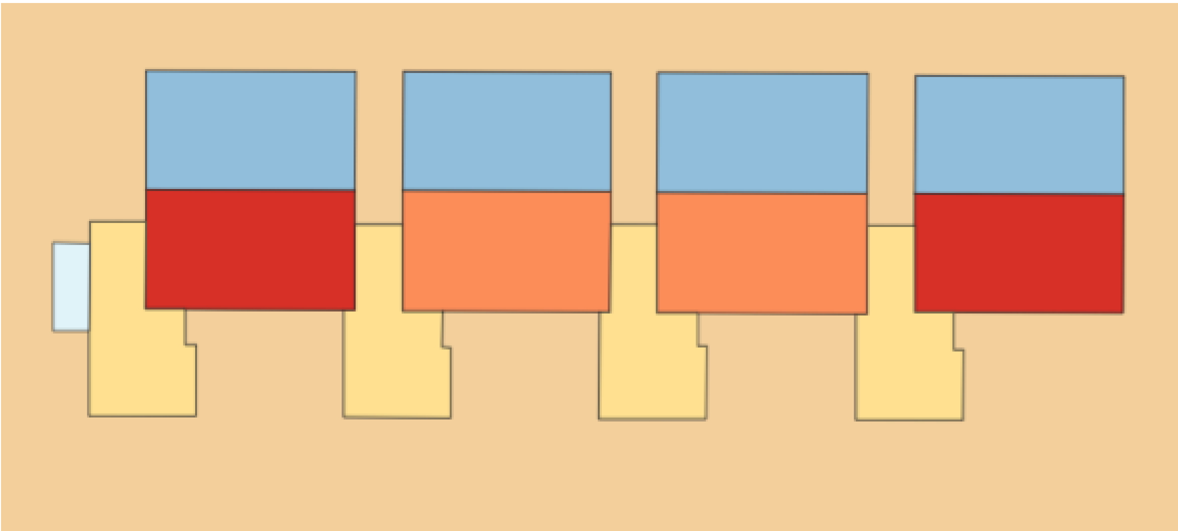


Figure 3.3 Suitability of roofs

Level of Detail

The level of detail in the maps varied between level 1 and level 2, five homes had a level 1 and nine level 2. The level 1 houses were in the countryside where the roof is just a square compared to inside the city where the data is more detailed and more information about the roof exists. However, no roof obstacle such as chimneys or dormers which affects both the placement of panels and shadowing exists in the map. HO11 described it as "*I would like to be able to split the surface, because the entire surface can't be used, there is a roof dormer and such there*". According to HO2, another company has a tool that helps with shadows from obscuring parts "*one company had something that showed how much the chimney and other things would shade the panels, then you could see much better than the starter map*". A comparison of two houses can be found in Figure 3.4 which has two separate neighborhoods with different LoD.

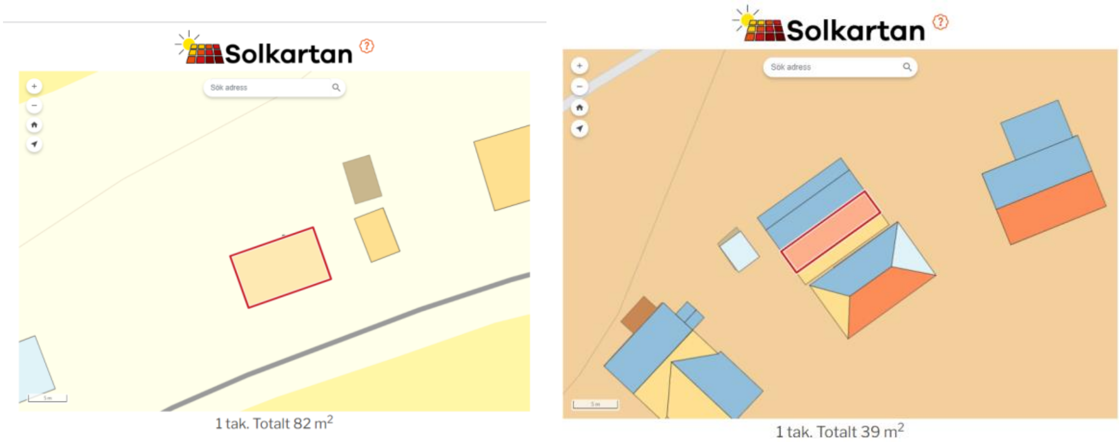


Figure 3.4 LoD of 1 and 2

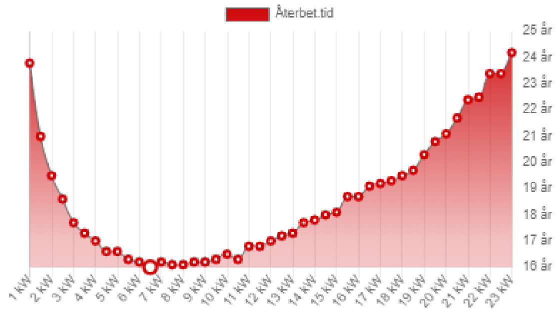
In the LoD 1 only one roof area can be selected while in LoD 2 up too three areas can be selected. Those with level 2 found it helpful and better than other on the market where you can only mark one area or choose one direction in which the roof is facing. HO13 stated *"here I can choose two sides but on the most I can only choose one of the, east or west facing".* Only being able to select three roof areas was limiting for two of the houses in the study where the participants wanted to look at several areas.

The ability to add more information that you know can alter the results are not possible but can for the knowledgeable add more value to the map and solidify the results. As HO13 suggests "*I think more flexibility where you can add more panels if you have some knowledge of your own, that would be very interesting, I know that it would come at a higher expense for the company, but it would give a clearer image that is more interesting to me compared to this. But using this set up that has the set values so that you have a starting point to alter from, that is nice".* HO4 also had trouble with the area markings, the roof in the map was not only theirs but included the neighbors as well which made them mark only the garage instead of the roof as they were not aware that not the entire roof would be fitted with panels, *"it was quite hard to get the panels on my roof, it's the wrong area because I live in a townhouse, so the marked area is for the entire house not just my part".*

Several expressed the desire for someone to come and look at their property in person in comparison to just get an offer based on satellite images. They were concerned about physical aspects as where cables and the inverter would be places as well as they felt as the price gauge was uncertain as no proper check had been made. HO7 put is as "*I have worked in IT so I know that if you write an offer with a fixed price without knowing the job than you add to it, which I then take less serious".* How trustworthy the results are perceived may be affected by the LoD as the area is not as detailed. The selected area is one of only two things the homeowner is providing to the model.

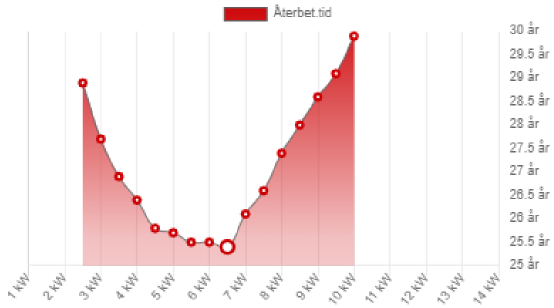
Size of system

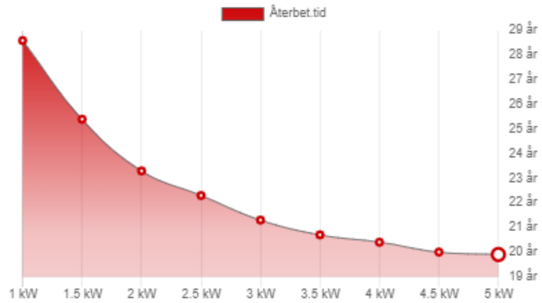
In this model the optimally sized system is based on the shortest payback time not the largest number of panels that the map assumes can fit the selected area. This gives systems at around 20 panels as was previously mentioned in 3.1. A sample of payback time curves that represent the four main shapes the participants received is presented in Figure 3.5. The B curve was the most common one with six participants, four received the A curve, C and D had 2 each. Those with curve D is limited by the selected area and C curves were smaller summerhouses with LoD 1.



Payback time A

Payback time B





Payback time C

Payback time D

Figure 3.5 The different type of payback time curves

Six of the participants wanted a larger system that either had more panels or a higher production as they had received from other companies. Six found the number of panels reasonable to the area and two thought the number of panels were too many compared to the area and wanted to reduce it. This is shown in figure 3.6. Some asked about the panel capacity in watts (W) as they were interested in getting closer to 400 W, the map does not provide an explicit panel capacity but a number of panels and a total capacity based on the default assumption, this results in panels about 325 W from the participants results. Given the curves in figure 3.4, ten of the participants can increase the system without any major increase to the payback time. HO7 says, *"for me, I want to invest in as many panels as possible, this is because I plan in the future when it is financially possible to get a battery"*. HO3 said "*I don't recognize these numbers [referring to number of panels] with what I have gotten from other offers, they are not where they should be"*.

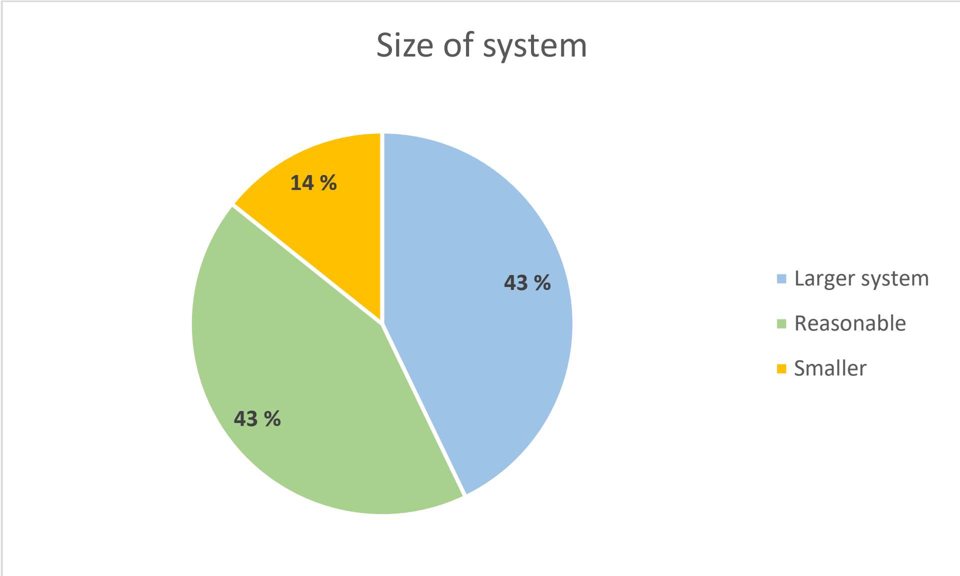


Figure 3.6 Size of the system

As previously mentioned, the payback time was perceived as long even if they were not that interested in the figure but believed that the actual system would perform better as the electricity prices will continue to be high. During the interview they were told that the recommended size was based on the payback time as some were confused what the size was based on because thought they had not made any decision on the webpage. Since payback time was not something they were that concerned with, the sizing seemed arbitrary. However optimizing the system based on something other than the available area assumed from the map resulted in not oversizing the systems. As HO5 stated on the optimization "*I think that is a good thing, because it is easy to just reach for the bigger one, you don't understand the benefit of it*". Five of the participants were aware that a larger system would impact the payback time in some way and four were not aware and was explicitly shown the curve instead, but as mentioned 10 of the payback times curves were not greatly affected by increasing the system. However as the map optimize the size at around 20 panels and some thought the larger the better, this could have affected how they perceived the results.

3.2.5 Understanding the system

From the interviews the most difficult part was understanding that you could not use all the produced energy and that you had to sell it or thinking it would increase profit if you sold more. This also affected how they saw the self-sufficiency in percentages as they assumed it should be higher by just looking at the total production. Understanding that the weather might change and that the electricity price is uncertain is maybe done unintentional by the comparison of the production in kWh instead.

Three asked why they had to sell some of the production and not use it for themselves, not understanding that they would need a battery for that. HO13 said "*that I have to sell my energy is one of the greatest downsides to Karlstads Energi, I don't want to sell my electricity but to save it so that I can use it later when it is darker in the fall or winter*". This person did not want a battery either because they are too small and expensive to store over seasons. As mentioned six wanted a larger system either more panels based on the available area or the capacity of the panels to increase production. This was based on what they can see on other houses or what they were recommended from other companies. Four were considering a battery in the future when the price is lower and therefore wanted a larger system now.

When asked if the website increased their understanding of the system, 12 answered yes and two were unsure as they were not well versed in the topic. The first image of the website, Figure 3.7 was well liked and after studying it during the interviews most were able to understand the basics while some still struggled and were not receptive of the information. One person felt as they should not have to know anything as that is what they are paying for, they need a physical person who will help them. HO3 stated "*I personally need human contact, it is too much information about the house for me to know, just so that it is correct when you don't have the knowledge of this*". The diagram of the demand vs the production each month was also appreciated as it helped with the understanding of the mismatch in production vs the demand. Five of the participants mentioned the staple diagram when talking about understanding the system or seasonal changes of the production and three were shown the diagram to explain why they had to sell part of the production.

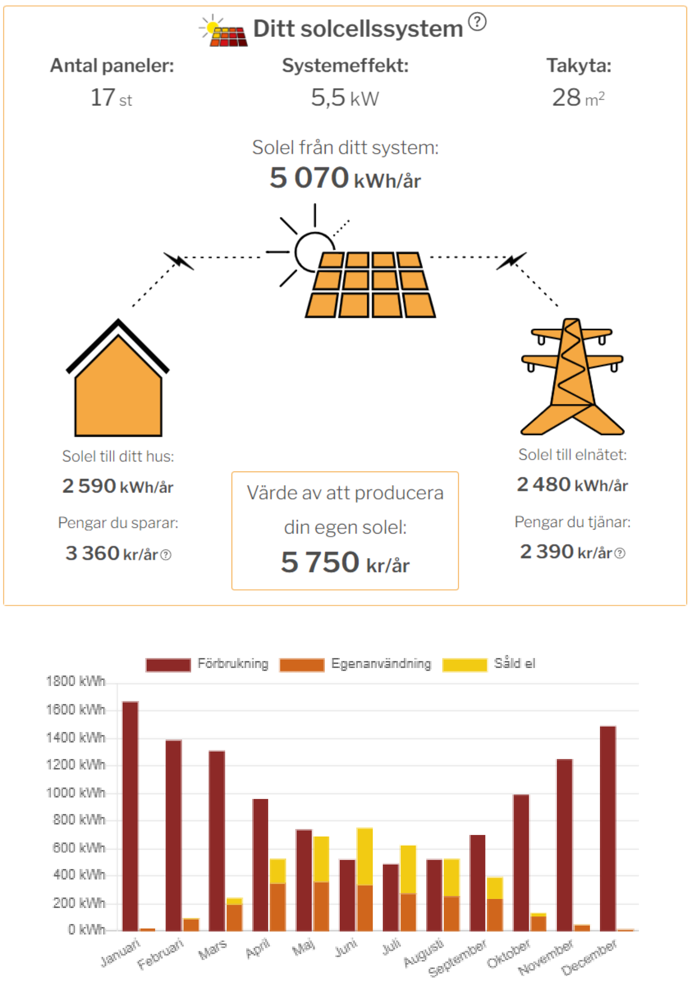


Figure 3.7 Results from the original map

3.2.6 Uncertainty of the future

Given the record high and volatile electricity prices this winter, the participants were somewhat aware of the uncertainty of the techno-economic results of the presented system. 70% of the participants think that the electricity price will continue to be high in the future and therefor making the system more profitable than presented on the website. They think the performance of the system is pessimistic and it will not be worse than presented. They stated that they prefer being presented with a cautious result and then have the system perform better than the opposite. As HO6 describes it "*I would have been dissatisfied if the results would have been that I would receive 100% of the capacity each year because that will probably never happen*". And HO1 *"yes, I think of it some and I get similar values from my calculations, there is some margin. It does not seem like fantasy results, and my neighbor gets more from their system than the calculations said. If it would have been the opposite, then margins might be too small"*. The hope is to even out the fluctuations by being less reliable of the grid and electricity prices. Some were aware that the weather data used could influence the results and wondered what location was used and if it was assumed to be sunny all the time. They often asked about the underlying assumptions and what was included in the prices to verify the results for themselves.

The continuous high electricity price may also be an effect of the electrification of society which will increase the demand of electricity. The current situation in Ukraine and pipelines from Russia was also mentioned as an uncertainty as the grid is connected to other countries. As the price is deemed uncertain the energy produced is more focused on as that is something that will be more constant and can be compared to their demand, this is also something that they can affect by choosing the size of the system and reduce their demand by changing appliances and habits.

3.2.7 Calculator

When asked about the calculator only one person remember looking at it compared to the data from the webpage where three people at least opened it and saw the function. The calculator was demonstrated during all of the interviews partly because of the sizing not matching the expectations and if they had questions about what data was used to come to the result. When shown the feature, nine participants said they would have used it of they found it. The feature was described as interesting, smart, fun and they liked that it exists. HO10 said *"It would be interesting to see if you increase the electricity price what would happen to the payback time and how much you earn from it"* and HO13 stated "*I like these types of setups where there is options and it is clear if you do something before the other. It is interesting to see the cost, payback time, earnings and such, I think its quite an attractive design to be able to test".*

The areas that they were interest in the most was the size, their demand, and the electricity price. Some mentioned that they did not feel knowledgeable enough to use the calculator to alter the results as they were unsure what input data was reasonable. HO3 stated "*this is exactly what I need help with then getting an offer, I should not need to have the specific* *knowledge for this, I am paying for that too*". One person also wanted the calculator to be more detailed as they wanted to add more specific information about their house.

As the solar map is designed to work on both computer and mobile everything is placed in column for easy use on a phone screen. On a computer this leaves a lot of space on the sides and some scrolling up and down to see the first diagram of size, production, savings and earnings. One person suggested it be placed closer to the diagram so that it is easier to see how any changes affects the system and therefore help with the understanding. They stated *"In this image you should be able to change the electricity price and demand so that you don't have to scroll up and down every time, when you jump between images you lose the information you had and give the impression that it is more complex that it is, with this first image in front of you than it is easier to understand".*

3.2.8 Credibility of the website

The credibility of the results was evaluated by the participants and nine found the results to be credible and reasonable partly because of the sender of the information. Of these two stated that it was more credible because they were not pressured to buy and that because this is not the prime source of income for the company it felt more reliable. HO7 said "*I think this type of information is more believable because I am not being sold something".* Several mentioned the results to be comparable and did not seem exaggerated compared to others. One even mentioned that they used the results as a reference value with other competitors. HO1 said "*the results seemed good, it felt serious compared to others I tested, I notices that it can vary a lot, several was in the same ballpark, but others were a lot different, the payback time seemed unreasonably short on a few of them".*

Three of the participants were not sure of the credibility of the results because of their limited knowledge but were positive of the sender and thought of them as reliable and maybe impartial. One person, when asked about the credibility of the website and the possible impartialness of the results, were for the most part okay with the results but believed *"someone is making money somewhere in this",* referring to the website not being impartial. One person was negative of the results based on what results they had received from other companies, they found the results worse and not updated to the current energy pricing situation.

The credibility of Karlstads Energi was partly because the respondents have previous experience as customers and had no issues with them or that they like the work in other areas and the general environmental work of the municipality. HO10 stated "*we don't have any previous bad experiences with Karlstads Energi and we have read that they have competitive prices*". Some knew others who had done installations using Karlstads Energi that were happy with the experience. The experience of others such as family and friends who had already installed systems were valued. Several mentioned that talking to others reassured them and some mentioned that they will discuss more with them for tips and advice before making a decision. The quality of the system is also an important factor and several mentioned that they would be okay with paying more for a higher quality from a company they trust and feel comfortable with. They also mentioned that they want to support a local business where they believed the proceeds from Karlstads Energi would go back into the municipality.

Due to the situation with delays of panels not all the participants were able to get a personalized offer before the interviews. They appreciated Karlstads Energi reaching out and explaining that there were delays but some stated that they would have liked an offer to better compare before making a decision. As a result of this some had chosen other providers because they wanted the system up as soon as possible.

The KTH logo is also shown on the website both when agreeing to the terms before using the map and if you expand the explanation of the map where KTH is mentioned as a developer of the map and research that the map is based on can be downloaded. This was done to increase the credibility of the map, however none of the participants mentioned KTH being linked to the map but were not asked explicitly about it or shown the parts of the webpage where the logo is.

3.2.9 Compare results

Of the 14 participants, seven have investigated other companies for other offers to compare the production, price and other personal interests. Other aspects that were investigated was if there was local personal who can look at their roof to get a correct evaluation and so that they can easily show up if there is an issue. Also where the products are produced because they have ethical standards for labor and what warranties that the company could provide for the materials. They generally compared three or more companies, only one looked into one other company than Karlstads Energi.

The other seven who did not compare were either not that far along in the process but wanted to compare or were happy with Karlstads Energi and wanted to support them due to them being local and trustworthy from previous contact or connected to the municipality and therefore beneficial to the community.

3.2.10 Other influences

When looking at offers and considering an investment there was some other factor that were taken into consideration. One important thing that was mentioned was that they wished someone would come to their house and do a physical check before getting an offer so that the offer was more based in reality and surprise costs were less lightly to occur. Local installers that would be able to come quickly if there was any issue was also considered as well as supporting a local business where the proceeds would go back to the community. HO4 said *"I would like someone local to install the system, is case there is any issue then they won't have to travel far, they would be able to come quickly and fix it, I think that is very important".*

They also wanted to feel good and as they were contributing, one person said that they like the feeling of charging their car on electricity produced by them, one said that it feels like they were contributing to the environment and society. Other environmental work done by Karlstads Energi and the municipality was also considered as HO9 mentioned *"I also consider* *that the municipality of Karlstad has done several other environmental project so I have trust in them".*

Aesthetics was also mentioned by four of the participants, they would select the number of panels to the most esthetically pleasing look and also asked what colors that is available for the panels. Other impact on the garden from the cables or where to place the inverter was also an important factor for some. Ethics as where the panels where produced to limit environmental impact and to support human rights was important to some. They wanted the panels to not be produced in China. Others also had demand of where the production took place but mostly out of quality concerns, they wanted to be sure the parts would last the expected lifetime and still operating at a high efficiency.

A future battery was a reason for some to increase the size of the system, they did not want to limit that possibility by taking away that option in the future. Some considered using a future electric vehicle as a battery for the system. HO1 said "I *want the future electrical vehicle as an accumulator when that is possible, so that we can store electricity let say Monday at 07 to Thursday at 18 and then use the car on Friday, Saturday and Sunday, it's something to consider for the future".*

4 Discussion

The reason to get solar PV was similar to Sommerfeldt et al. (2022) and Palms study (2018) where wanting to make a profit from the system was the primary reason as the technology is seen as mature by users. However, the high electricity prices during the winter were the catalyst for several of the participant which shifted the reason somewhat to savings instead of making a profit from the investment. This is still a financial reason but changes how they perceive the key figures of the investment. From the interviews the figure that is the most important to the users is the produced electricity in kWh that they are directly comparing to their demand preferred presented in yearly figures instead of monthly. This is contrary to when the map was designed where the payback time was used to determine the system size. Those who had the environment as primary reason, which was three participants, were not presented with a lot of information regarding their interest. The environmental benefit is presented as distance driven by an electric vehicle which only a few of the interviewees have or are interested in getting. It is difficult to design a website which can cater to all interests. Perhaps if the user could fill in their reason for looking at investing before the results are presented which would then alter how results are presented to the user. Though the reason to invest was usually a combination of both economic and environment which then again leads to difficulties designing the website and how result are presented.

The simplicity of the website was appreciated as it requires little from the user while still provides instant results that can be done an any hour of the day from you own home. However not the entire website is utilized by many and the information is not always understood. In this study some of the users did not understand the miss-match in production and demand over the different seasons and why they must sell their overproduction. This affects the self-sufficiency and does not match their perception of how much of their demand will be offset by installing PV by just looking at the production vs demand (Falkenström & Johansen, 2020). They were however aware and understanding of the future uncertainty of for example the electricity price but not how this affects the financial results.

The participants did not express that they were missing any information on the website but they are based on the usage not utilizing the entire website. Most of the participants did not use the calculator but found it very interesting and would have liked to use it. Using the calculator may help with the understanding of the system, the affect size has on the payback time and the uncertainty of the future from electricity price for example.

Using the calculator can also help with the sizing of the system as five wanted a larger system/more production compared to the first presented one. “Bigger is better” may come from that they compare kWh and not payback time and partly because that is what they are getting from other providers. If the user did not expand the economy or the calculator they might have assumed the presented system was the largest system possible and might have been disappointed as they were comparing the produced kWh to their demand. As seen by the payback time curves in Figure 3.4, 70% of the participants can get a larger system that would not affect the payback time significantly and they can usually fit more panels than the optimally presented system based on Figure 3.1. Filling all available area with panels might be what other provides are doing which could impact why uses saw these results as too low (Sommerfeldt et al., 2022). The sizing using the payback time was however useful as to not present a system only based on size and that would have resulted in too large system based on the data available in the LoD which assumes more area is available than it actually is. The size of the system might be getter presented as a range with possible sized together with an explanation to the affects of choosing a larger than optimal system.

LoD of the roofs also affects the size of the presented system. The map generally overestimates the maximum number of panels compared to the calculated maximum. If the Data used in the 3D-models were of higher LoD the over sizing based on area might be removed but the optimal size is based on the input variables (Zhou et al., 2022).

Some have a reasons for getting a larger system as they plan to get a battery in the future when it is more financially viable. Payback time was not of interest, but they still found it too long, and longer than other providers. As payback time is dependent on what data goes into the calculation in form of subsidies, electricity buying and selling price this varies a lot between providers(Sommerfeldt et al., 2022). Seeing these figures in the calculator may help with comparison and understanding the financial calculations that results in the payback time. However the users stated that they do not have the knowledge to alter those parameters in the calculator with confidence. One addition to the calculator could be the option of changing the capacity of the panels as panels as large as 400 W was requested by some and would as well help with the comparison of results between providers for the user.

Their interest in the field affected how they used the website and what areas they focused on. Those with little interest in the technology did not really study the results before continuing with the interest form as they preferred a person to talk to and did not think they were knowledgeable enough to have an opinion on the results (Palm & Eriksson, 2018). Those with more interest and knowledge hade more questions about what input data that was used for the economic results and wanted to compare more.

The demand entered by the user also affects the size of the presented system more than the available area based on the selection method of the website. However the demand was not always known by participants in the interviews meaning that the demand entered might not be accurate which can affect the size they were presented with. As the size was something that many found important this could be an issue of not pleasing the users wants due to an error of their part also because they did not find the calculator (Falkenström & Johansen, 2020). The site seems to have input data which gives a bias towards systems of around 20 panels or a system of 6,5 kW. As seen in Table 3.1 the number of panels presented is similar regardless of the demand.

The number of areas to mark in the map varies with what LoD is available in the map. Being able to mark more than one area in more than one direction is quite useful for several homeowners. It you now want to select more than three it is not possible, and the map will just give you a pop-up sign saying that. One alteration could be to give the user a heads up that they have marked three areas and ask if they want to add one more. It is good to have a limit as sometimes you might mark an area while zooming or by accident so that you only end up with the specific areas you want to use.

The layout of the website is elongated so that it can be used both on a computer or a mobile device. As suggested by one of the participant maybe the calculator should be next to the first diagram so that any alterations are clearly visible to help with the understanding. This would however not be available for mobile devices which leads to two separate websites which will add cost to the developing. However what device they were using did not affect the time spent on the website or what tools were used.

The trustworthiness perceived of the participants was not only with regards to the results but also the sender which in this case was Karlstads Energi. According to Falkenström and Johansen (2020) the purchasing factors were based in quality, price, trust and brand recognition where quality was important and price was less of a deciding factor. Similar to the results of this study where some participants expressed that they were okay with spending more if the quality or value of the investment increased as this was already a big investment for them so they wanted to make smart choices. Karlstads Energi was recognized and trusted based on previous experiences with gave validation to the results and reassurance. However some did not see the website as results and were waiting for their personalized offer before actually taking a stance on the results. They did not trust the website to give a result that was accurate enough and felt more secure if their property was viewed in person before an offer was made. Other trusted sources were people who had already installed PV. Their input was very valued to know more about what to think about before installing.

Limitations to this study can be the small number of interviews and the bias of the demographics. All of the interviewed were positive towards solar PV for their homes they were just in different phases of the process in maybe getting a system. Opinion and thought of people who did not find the website intriguing enough to proceed with the interform cannot be found in this paper. The demographics are not representative to Sweden but is however comparable to other studies with similar participants.

During a solar fair in Karlstad where Karlstads Energi was present and demonstrated the solar map similar trends of users looking for the produced energy as the most important aspect was also noticed. This aligns with the results of this study and provides some confirmation for the results of 14 participants, which is not a large enough sample size to generalize the conclusions. The results can be used a guidance in the work of achieving more effective communication of online communication techniques for solar PV.

To gain further insights about household investment is solar PV more research is needed. Further studies which should include a larger sample size of a broader demographics and participants with different attitudes towards solar PV. This can expand the topic and help nudging potential prosumers towards investment in solar PV while also not using overly optimistic results.

5 Conclusion

Designing a website where the user is not required to enter a lot of information and still providing results of high quality and accuracy while also conveying the user with useful information that they are interested is quite hard to achieve. The users come with different reasons for investing and have varying knowledge of the technology which limits the understanding and ability to compare results.

From this study the main reason to invest was financial with the environment as secondary reason. Due to the high electricity prices currently experienced in Sweden the participants wanted to reduce their monthly costs by installing solar PV while also becoming more self-sufficient and help the environment. To be able to provide each user with information regarding their interest and reason for investing results in several areas is necessary. Some find the amount of information too much and difficult to understand, but the majority are reassured by information and find the result more trustworthy if assumed input data is presented and can more easily be compared between providers. The reception of honest representation can vary from what the user has received from other offers. Not providing overly optimistic results compared to other providers can set honest providers back in the views of some while others find the results reasonable.

The quality of the 3D-models used for solar maps does affect the quality of the results where both the size of the roof and obstacles on the area are important factors to include. Larger PV systems than presented were possible in 10 out of 14 cases while not affecting the payback time significantly. However the maximum system size found by the map was larger than what was calculated possible in the majority of the cases. To better compare with other providers and better match what the users are looking for the panels capacity can be increased close to the maximum available commercial sizes.

Understanding how the system operates appears to be the most difficult part for users. Some are unaware of why not all electricity produced can be used by them directly without using a battery and therefore having to sell it to the grid. The users seem to understand uncertainties about the future by choosing to compare produced electricity in kWh to their annual demand instead of payback time but are not knowledgeable enough to alter the input variable that determine the payback time. The calculator may help with understanding the uncertainties of the future, helping with understanding the system and why larger systems may not be the most financial decision based on current data and knowledge.

As all the participants in this study were already positive toward getting solar PV for their homes the preferences may not be applicable to the general investor but they preferred that someone showed up to their house before making an offer and that the company was local to be able to come if there was any issues. Some also have other criteria such as aesthetics, ethics as well as warranties of the quality.

The trust of the participants was also based on sender and not just the results of the system. Due to previous contact or recognition of Karlstads Energi the users wanted to get an offer from them. Having someone seeing their property in person before the offer is made is also highly valued. They were positive to Karlstads Energi as sender of the information and it increased the trustworthiness of the results.

The ability to effectively convey information that is useful, attractive, and trustworthy is based on the user. There is not one perfect design that will work for all users as the users have different knowledge and interests going in which varies the utility. The framing that is the most favorable is using the yearly production in kWh described as a financial investment focusing on savings from the system together with environmental aspects. Users base the trust of the results on more than the figures. Previous brand recognition as well as opinions from previous users weigh in when evaluating the results before decision making.

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7 Appendix

A Timeline of interview

Introduction and start of recording.

Why are you interested in getting solar PV for your home?

Hur kommer det sig att du är intresserad av att skaffa solpaneler till ditt hus?

Ask about the different website version and for any particular they like or dislike.

Q1. What information convinced you to continue with the interest form?

Vilken information som övertygade dig att sicka in intresseanmälan?

Q2. Did you get the information you need to make an informed decision?

Fick du informationen du behövde för att ta ett välgrundat beslut?

Q3. Is there a graph, data or feature that you are missing from the website?

Tycker du att det saknas någon graf, data eller funktion på hemsidan?

Q4. Did the information provided help your understanding of the system and the investment?

Kände du att informationen hjälpte din förståelse av systemet och investeringen?

Q5. Do you think about how the performance of the system could be different from expectations?

Tänker du på att resultatet från det faktiska systemet kanske inte kommer vara densamma som presenterats då framtiden är oviss?

Q6. Were the features of the website useful towards your understanding of the system?

Var det någon funktion på hemsidan som du tyckte var användbar för att öka din förståelse systemet?

Q7. How credible did you perceive the website and results?

Hur trovärdig uppfattade du hemsidan och resultatet?

Q8. Did you compare the results with any other provider or independent source?

Jämförde du resultaten med någon annan aktör eller oberoende källa?

Q9. Does anything else influence your decision?

Är det något annat som påverkar ditt beslut?

At the end of the interview before the demographics is asked they are reminded that they are anonymous and will not be mentioned by name. The demographics are asked, this is age, gender, education level using set levels, and monthly salary within brackets of 10 000 SEK.

B Calculated Yield for Karlstad

Table B.1 Yield kWh/kW for Karlstad

Tilt angle / Azimuth	20	25	30	35	40	45
-100	653,336	643,348	633,453	623,408	612,878	601,747
-90	680,42	675,554	669,857	663,16	655,169	645,938
-80	706,954	706,895	705,168	701,634	696,11	688,794
-70	732,322	736,789	738,839	738,37	735,32	729,6
-60	755,889	764,567	770,146	772,488	771,897	768,086
-50	777,045	789,509	798,348	803,411	804,831	802,907
-40	795,219	810,923	822,429	829,942	833,263	832,622
-30	809,917	828,317	841,983	851,223	856,219	856,819
-20	820,851	841,159	856,654	867,294	873,314	874,966
-10	827,914	849,555	866,14	877,808	884,582	886,498
0	830,909	853,073	870,032	882,067	889,413	892,051
10	829,51	851,572	868,711	880,793	887,812	890,002
20	823,924	845,203	861,423	872,776	879,616	882,054
30	814,29	833,876	848,732	859,247	865,198	866,482
40	800,568	817,736	830,847	839,667	844,165	844,892
50	782,977	797,121	807,608	814,091	817,122	816,363
60	762,057	772,527	779,693	783,721	784,559	781,869
70	738,334	744,453	747,937	748,98	747,043	742,633
80	712,292	713,539	712,921	710,478	705,948	699,548
90	684,667	680,543	675,381	669,223	661,875	653,019

C Original quotes used

The quoted in the original form in the order they are used in the report.

HO7 det är i alla fall ingen direkt förlustaffär jag tycker jag får in extra el, och ur miljösynpunkt så vi har ett stort tak, så kan man göra det och jag har råd att göra det.

HO6 jag visste att någon gång kommer betala sig, jag kollar bara vad jag skulle kunna få ut i strömmen

HO6 hur mycket kilowattimmar per år som vi skulle få ut, det var det viktiga

HO5 jag tror att det är elpriset kommer nog ändå, det kommer nog vara högt även sommartid om vi ska elektrifiera samhället i den utsträckning som det är tal om

HO12 ja, det blir lite abstrakt att man ska köpa för 80 000 och så ska man liksom spara 388 kr, man blandar storheterna lite kraftfullt kan jag tycka, för det här blir ju mer som en investering, då vill man ju veta lite i de stora dragen

HO12 jag får ju bättre avkastning på börsen normalt sett en 3,31 % liksom, det är ju rätt dåligt, jag är nog mer på inne på original då

HO3 jag tittar ju naturligtvis på återbetalningstiden, jag tittar på självförsörjningen kanske inte så mycket i procent utan jag är mer inne på kilowatt

HO1 Jag ville hamna på så att jag ungefär tog halva årsförbrukningen och det gör jag ju med den här kalkylen så det var det som var intressant, får jag halva av det jag förbrukar så är jag nöjd

HO12 hade det varit det till 80 000 och 2 000 kilowatt ja, då kanske jag hade sagt till barnen att de ska släcka lampan istället, det här känns görbart

HO5 jag är nog en sån som ändå gillar information, hellre att jag får för mycket och han kan avgöra själv, och detaljer tycker jag liksom om

HO3 så för min del så tycker jag att alla de här procentsatsen det blir så många siffror och hålla koll på, jag vill veta egentligen vad kostar investeringen, återbetalningstiden och hur mycket jag kommer och producera själv

HO12 det är väl enkelheten i också att gå vidare med intresseanmälan, så är det gratis och det är ändå bara att skicka in, man behöver inte ta vidare kontakt, man behöver inte jaga en hantverkare**,** och sen känner vi några som har liksom investerat i det här via Karlstads energi så att det på något sätt känns tryggt liksom

HO5 jag gillar ju liksom färgskalan och alltså det är väldigt trevligt gränssnitt det är ändå och det är enkelt att förstå och ta till sig, man blir ändå, jag kände att det blev, det här är ändå görbart, det här är ändå, enkelheten i det

HO7 det var väl mer att det var görbart, det är väl så här själva syftet gissar jag, alltså det här är ju att få att få människor intresserade på ett väldigt enkelt sätt, alltså att kunna förklara någonting som man egentligen inte är insatt i på ett enkelt sätt

HO11 jag skulle vilja dela ytan också, för att det är inte hela ytan som går att använda, det är ju liksom takkupor och sånt där

HO2 ett företaget hade ju använt vet inte vad, för då fanns det skorstenar och grejer och hur mycket skorstens skulle jag kunna skugga och sånt där på solpaneler, så att då såg man ju mycket bättre än från den kartan som fanns från början

HO13 om man tänker sig ett flexibelt där man har möjlighet att kunna lägga fler celler, om man har lite egna fakta, det tycker jag är väldigt charmerande och man skulle kunna tillåta sig att bjuda på det, det kostar från företaget i och för sig, men det ger ju en för mig en helhetsbild som är mer intressant än den här bilden utifrån som det är i nuläget. Men gärna med det här upplägget, med givna mallar och såna här saker, men att man kan använda vissa givna värden som man kan utgå ifrån från början, och sen att det är liksom omvandlas utifrån de här perspektiven då, det tycker jag skulle vara himla trevligt

HO4 det var väldigt svårt att få fast panelerna på taket här, det blir fel yta, för jag bor ju i radhus, så att när jag skulle montera och sätta dit de här panelerna så blir det ju på hela radhuset yta

HO13 nu kan jag välja 2 sidor men på de flesta sajter så kan man bara välja en av dem, om det är öster eller västerläge

HO7 jag jobbat i IT branschen så och skriver man en offert på fast pris utan att ha koll på vad det är, då lägger man ju på en hel del jag tycker jag inte det var seriöst

HO7 jag tänker så här, att man vill ju installera så många paneler som möjligt, faktiskt därför att på sikt så ser jag ju att jag kommer att skaffa ett, när det liksom blir ekonomiskt och verkligt att ha ett batteri

HO3 jag tycker inte siffrorna stämmer med det jag har fått offerter på, det är det som jag liksom ja, jag känner inte igen den

HO5 det tror jag är det är väldigt bra, för att det är lätt att man att man bara sträcker sig efter en större kaka liksom, man inte riktigt förstår nyttan av det

HO13 ja, och det är ju det som jag tycker är karlstads energis stora minusposter, att jag inte kan spara det, jag vill jag vill egentligen inte sälja min el, utan jag vill spara det så jag kan använda det lite senare, när det är i ett mörkare tillstånd eller på hösten och vintern

HO3 för min del så behöver jag ha en mänsklig kontakt, det är lite för många uppgifter om huset sen för mig att fylla i så att det blir rätt och riktigt om man inte har kunskap i det

HO6 jag hade nog varit missnöjd om att det står att man ska få 100% varje år och kommer ju i princip aldrig hända

HO1 Ja lite funderar man ju det och liksom räknar man på det så ser man att det finns ju marginaler åt rätt håll så att det känns ju inte som en fantasi kalkyl, utan jag ser ju på de grannarna vi har som har satt upp som har använt liknande beräkningar att det levererar lite mer än vad vi har räknat på här i exemplet, och det är ju positivt när det är åt det hållet för hade det varit åt andra hållet, ja då hade man ju kanske börjat fundera lite grann, på att det är små [marginaler]

HO10 man kan ju simulera lite olika här då, det kan vara intressant att se om man höjer elpriset då vad händer då med återbetalningstiden, och hur mycket man tjänar på det, men det är klart det blir ju den förbrukning som man får från annat håll blir ju också dyrare

HO13 såna här upplägg tycker jag är bra, där man har alternativen och det blir rätt tydligt om man gör det ena före det andra, och sen kan det vara intressant att se vad det kostar och återbäring och allt det, till livslängd å ena med det fjärde, så att det där tycker jag är rätt attraktiva alltså som design att kunna testa

HO3 det är exakt det som jag vill då ha hjälp med när jag gör en intresseanmälan och jag får en offert, […]alltså det är exakt den info som jag behöver få, för att jag ska inte ha detalj kunskapen om det här för att jag köper den också

HO3 i den här bilden skulle du kanske kunna justera med elpriset upp ner förbrukning upp det så att du inte behöver scrolla utan du är på samma bild hela tiden, det här när du hoppar emellan olika bilder eller olika sidor på nätet då hinner du ju tappar den information du hade innan, det kan ibland ge uppfattningen att det är mer komplext än vad det är, med den här får du hela tiden bilden framför dig här, då med huset, panelerna och försäljningen eller nätet, då har du ju den med dig hela tiden och då är det enklare att förstå

HO7 jag tycker att den här typen utav information är mycket trovärdigare just därför att man inte försöker sälja på mig någonting

HO1 ja men jag tyckte det kändes bra, det kändes som ett seriöst resultat för efter den här så var man inne och testade lite andra, som en del leverantörer hade, där såg jag att det spretar ju väldigt, jo det har ju flera som hamnat på ungefär samma sen var det ju sådana som stack iväg väldigt mycket, ja återbetalningstiden kändes orimligt kort på ett par stycken

HO13 men det är väl någon som ska tjäna på någonting i något läge va

HO10 vi har väl inga dåliga erfarenheter av Karlstads Energi sen förut om man säger så va, sen det som man har läst om KE så har dem ganska konkurrenskraftiga priser

HO4 ja, jag vill nog gärna ha någon som installerar som är lokal lokalt förankrad, det tycker jag vore väldigt bra, och så att om det blir något krångel att dom inte ska åka långt, utan de ska kunna komma snabbt och fixa till liksom, om det blir fel, det är ju jätteviktigt tycker jag

HO9 ja och sen tänker jag att det Karlstads kommun har gjort en massa bra miljöprojekt så jag känner lite förtroende så här

HO1 ja, det är tanken att jag vill ha den som är ackumulator när den funktionen kommer. Att jag kan se att om vi cyklar till jobbet kanske måndag till torsdag och fredag lördag söndag vill vi använda elbilen, när man får ett så pass smart system som vi kan tala om allt ifrån en måndag säger 07 fram till torsdag 18, så får bilen funka som en ackumulator emot växelriktaren, och att man kan ladda och använda den energin som finns där, men sen att man låser den ifrån fredag och till söndag, så att man inte att man bara laddar och inte förbrukar ifrån den, det är en sådan tanke som jag ser lite längre fram.

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