Possibilities for solar power in a community

Usage of solar panels in Ruusutarha allotment gardening

Bachelor's thesis

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ABSTRACT

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ABSTRACT

This Bachelor's thesis commissioned by Milectria Oy. Milectria is a company producing electrical systems, and it is specialized in wiring harnesses, cable kits, distribution boards and electromechanical assemblies. Solar power and systems around it are a new field of operations for it. The company is taking part in an allotment gardening project that is planned to be built in Aulanko in the city of Hämeenlinna. This modern allotment gardening, called Ruusutarha, is a project started by a house manufacturer Teijo-Talot Oy, who got interested in the possibility of using solar power in the cottages of Ruusutarha.

The purpose of the thesis was to find out how solar power could best be exploited in the case of Ruusutarha. The power usage within a community was one of the main matters, and special attention had to be paid it. By studying different techniques and approaches, all the possible applications were introduced, and the most suitable ones were delimited. The information for the thesis was searched for both in printed and online sources. The material was gathered, especially, on solar energy, installations and electro technical matters concerning it, and for permit work required when assembling a solar power system. The plans were made with the help of the experts in the field.

Even though an effective production of solar power in Finland is limited, during the most efficient months, the power production can be as much as elsewhere in Europe, or even more efficient. The prices of the devices have decreased during the past years, and in the future when the battery technology develops to a profitable level, usage will become even more viable. The exploitation of community is a point of view that could be discussed more, especially in the case of new construction.

Keywords solar energy, solar power, solar panel, micro production

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TIIVISTELMÄ

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TIIVISTELMÄ

Tämä opinnäytetyö toteutettiin toimeksiantona sähköalan toimijalle Milectria Oy:lle. Yrityksen toimialaa ovat johdin- ja kaapelisarjat, sähkökeskukset ja sähkömekaaniset kokoonpanot, sekä uutena kohteena aurinkosähkö ja sitä koskevat järjestelmät.

Milectria Oy on mukana siirtolapuutarhaprojektissa, joka on suunnitteilla rakennettavaksi Aulangolle, Hämeenlinnan kaupunkiin. Ruusutarhan moderni siirtolapuutarha-alue on talopakettivalmistaja Teijo-Talot Oy:n hanke, jossa aurinkoenergian hyödyntäminen nähtiin mahdollisena.

Työn tarkoituksena oli selvittää, millä tavalla aurinkoenergiaa voitaisiin parhaiten Ruusutarhassa hyödyntää. Erityistä huomiota tuli kiinnittää aurinkoenergian hyödyntämismahdollisuuteen yhteisönä. Erilaisten tekniikoiden ja lähestymistapojen läpikäynnin avulla haluttiin tuoda esille mahdolliset sovellukset ja rajata sopivimmat niistä.

Työtä varten on haettu tietoa sekä painetuista että sähköisistä lähteistä. Aineistoa on kerätty erityisesti aurinkoenergiasta, siihen sovellettavista laitteista ja sähkötekniikasta sekä aurinkosähköjärjestelmän perustamiseen liittyvistä lupa-asioista. Lisäksi suoraan Teijo-Taloilta saatua materiaalia on käytetty. Suunnitelmat on laadittu yhdessä asiantuntijoiden kanssa.

Vaikka aurinkosähkön tehokas tuotto Suomessa onkin rajoittunutta, voidaan tehokkaimpina kuukausina tuottaa yhtä paljon sähköä kuin muualla Euroopassa tai jopa enemmän. Laitteistojen hinnat ovat viime vuosina laskeneet kannattavalle tasolle, ja tulevaisuudessa akustojen kehityksen myötä tulee kannattavuus nousemaan entisestään. Yhteisöllisyys aurinkoenergian käytössä on näkökulma, jota voitaisiin etenkin uusien asuinalueiden rakentamisen yhteydessä pohtia enemmän.

Avainsanat aurinkoenergia, aurinkosähkö, aurinkopaneeli, mikrotuotanto

Sivut 41 s. + liitteet 4 s.

CONTENTS

1 INTRODUCTION

The world how we know it today is run by fossil fuels. Cheap oil, natural gas and coal have enabled the growth we have reached in both welfare and economy. The last 150 years have been particular times for human kind in that sense. The western culture is thoroughly dependent on fossil energy, but the fact is that it cannot continue that way for too long anymore. Now that it has been noticed that these energy sources will run out at some point, we are forced to find other solutions. The challenge is to meet the growing need but at the same time limit the loads. During these one and a half centuries, our society has taken huge leaps on science and technology but it has happened at the expense of the planet. Global warming together with diminishing energy sources and growing energy needs are pushing us to develop alternative energy production systems. (Laitinen 2012, 15-17.)

It is clear that solar energy will be one of the most important solutions for the world's energy problems. Solar radiation is available almost limitlessly and it does not have the same disadvantages as some other green energy solutions. It does not have that big influence on landscape, land use or emissions like wind or bio energy. So far, the usage of solar energy has been limited mostly due to the price of technology and poor efficiency, and also due to the fact that the sun does not shine all the time. Sometimes it can be difficult to make the demand meet the supply. However, many people believe that solar energy will break through on a large scale.

There are two ways to produce energy from the sun. The other one is to generate heat and the other one to generate electricity. On a global scale, solar power is more important than solar heating. The most common application for producing electricity from the sun is a solar panel that consists of solar cells. The panels can be used either individually or they can be assembled in groups forming many hectares large power stations. (Laitinen 2012, 57-59.)

In Finland around 40% of the energy is consumed in buildings. The Ministry of the Environment in Finland has set a legislation on the energy efficiency of buildings. The intention of the legislation is to promote energy efficiency and usage of renewable energy. The European Union has also set a goal that all new buildings would be nearly zero energy buildings by the year 2020. Fulfilling this goal could mean that solar panels and collectors together with small wind turbines become ordinary equipment in every house. In any way, construction industry has a great part in the movement towards a more sustainable society. (Ministry of the Environment)

In the project Ruusutarha it was desired that in addition to regular electricity supply the solar power could be exploited. These two power systems can be used in conjuction. The project leads by an example and shows how the actions can and should be taken.

2 RUUSUTARHA AS A PROJECT

Ruusutarha allotment gardening is a project representing new allotment construction for a modern consumer. The site of Ruusutarha is located in the respected area of Aulanko, only a few kilometres away from the city centre of Hämeenlinna. The history of Aulanko starts from the 1800s when Colonel Hugo Standertskjöld founded the park, and nowadays it is a large recreation and tourism area. Besides the City Park the area offers variable activities from golfing and other outdoor sports to spa treatments and open-air theatre. As an area, Aulanko is very well suitable for a modern allotment gardening. There modern living can bind together with nature, and usage of clean energy only confirms the union. (Ruusutarha)

2.1 Companies involved in the project

Ruusutarha allotment gardening is a project started and managed by Teijo-Talot Oy. Teijo-Talot is an ordinary house manufacturer who claims to be “dull due to all the easiness”. What makes the company special is that they make their buildings fully complete in their factories. Everything from the foundation until the finishing inside the house are made indoors in their halls protected from the weather. Even lamps can be attached before taking building on the site. Teijo-Talot has their own technique for moving a building as one piece from their factory to the final destination. The bigger buildings are constructed in a few modules that are joined together on the site. The earthworks on the construction site are made so that the attachment hatch inside the house will coincide with the corresponding position on the plot. The hatch is later sealed and it cannot be noted from the ready-made building. The cottages designed for Ruusutarha allotment gardening are small enough to be moved as one piece. (Teijo-Talot)

Teijo-Talot is the main constructor of the project Ruusutarha, but it cooperates with a company called Milectria Oy. Milectria is a company producing electrical systems, and it is specialized in wiring harnesses, cable kits, distribution boards and electromechanical assemblies. Solar power systems are a new field of operations for them. As a company focused on electrical systems, Milectria has plenty of knowledge about the electro technical items that also consist of solar power. In Milectria, they believe that solar power will succeed, and that taking part in the development is rewarding. (Milectria)

2.2 History of allotment gardening

The history of allotment gardening starts from the end of 1700s from England. The idea then was to offer allotment areas for gardening for poor people and that way to save the government’s money in poor reliefs. Later the idea moved to the continental Europe and at the beginning of the 1900s it arrived in Finland. The First World War caused a shortage of food which accelerated the establishment of new allotment gardening. Also in Hämeenlinna, there is one traditional allotment gardening. It was founded in 1933. (Figure 1).

Suomen Puutarhaliitto defines allotment gardening in the following way: “A small garden situated in conurbation or nearby it having allotments forming a coherent entity. The area reserved for cultivation that is separated in allotments size of 200-500 m2. It is allowed to construct a lightweight cottage on the allotment.” (Siivonen, Salonen & Kucha 1999, 26-27.; Kantolanniemen siirtolapuutarhayhdistys)

Figure 1 Allotment gardening in Kantolanniemi, Hämeenlinna

2.3 New allotment construction

The idea of Ruusutarha allotment gardening comes from the old days, but the implementation is more suitable for modern times. The plan is made for 80 cottages that are situated in four blocks (Figure 2). Each of the cottages has their own plot of 400 m^2. The floor area of one cottage is 25 m^2 and in addition, there are sleeping lofts of 7.5 m^2, which are enabled due to high slanted ceilings (Figure 3). The cottages are equipped with electric underfloor heating, a small kitchen and a bathroom. In addition to the main cottage, it is allowed to have two lightweight buildings on each plot. The other one can be a shed with a maximum size of 6.0 m^2 and the other one can be a pergola with a maximum size of 8.0 m^2.

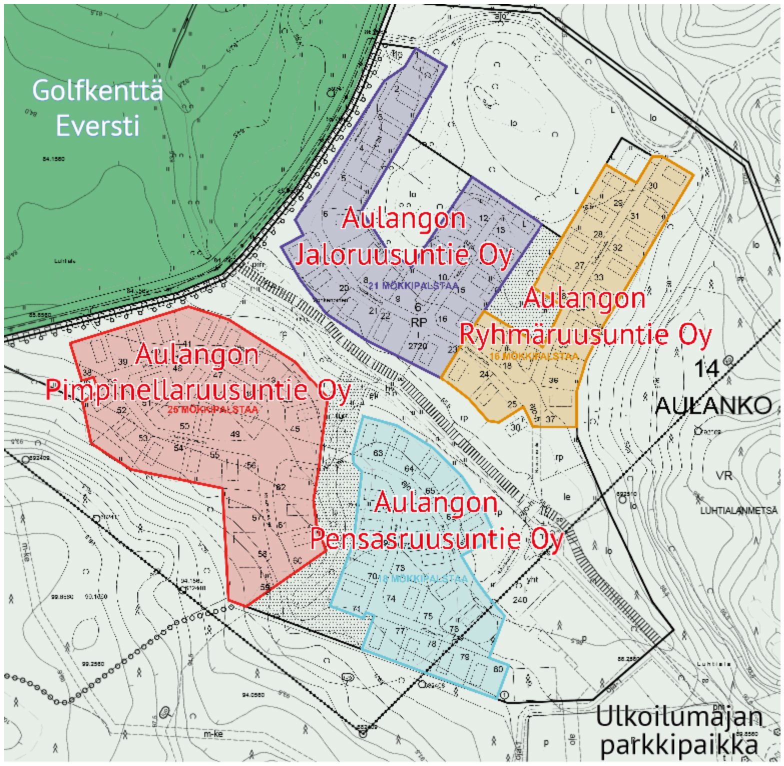

Figure 2. Four plots; Section taken from the area map

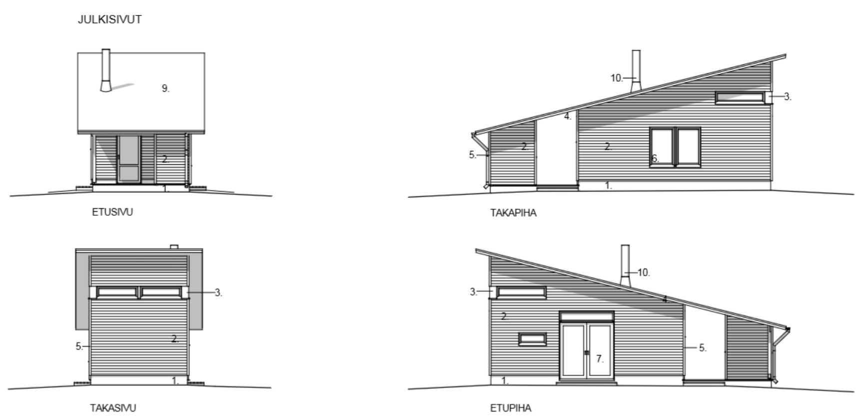

Figure 3. Elevations of the cottage

2.4 Power generation in a community

The idea of adding solar panels to the cottages came from Milectria. Teijo-Talot got interested in the possibility, and wanted to know more about the concept. In practice, creating a solar power system is not too difficult, but designing is complicated. Like all technical designing, there is a large variety of possibilities and usually it is impossible to point out only one correct approach. Also, the money reserved for a project might limit the options and make designing more difficult.

The case in Ruusutarha is interesting due to the chance of using solar power in a community. The most is achieved when the electricity grid is shared between the cottages, and in that way solar power left over from another cottage can be used in the other one.

Assembling solar panels might require a building permit from building inspection in some municipalities, but usually action permit is enough. Installing a solar power system also has to be discussed with the electricity supplier when the system is attached to a regular power grid. If there is power left over, the surplus power can be sold to the supplier with the agreed price. Practices vary in Finland quite a lot since the whole operation is rather new. The practices are discussed more in Chapter 6. (Finnwind)

3 SOLAR ENERGY

Solar energy belongs to renewable energy sources as the energy that the Sun is producing is not diminishing while we are using it. We do know that the Sun will stop its production some day, but it will happen in such a long in the future that us humans do not have to think about it in millions of years. The other energy sources like oil, coal or natural gas are burned in order to get the energy from them. Combustion releases greenhouse gases that accelerate global warming. Both global warming and greenhouse effect are natural phenomena but due to the emissions of greenhouse gases like carbon dioxide, the greenhouse effect strengthens and that again leads to more intense global warming. Global warming is a big concern since it makes glaciers melt and sea levels to rise. It also causes heat waves, drought and extreme changes in the weather.

Many people are slowly starting to understand how important it is to take care of the environment. Energy efficiency of residential buildings is becoming a more and more important factor for the house buyers. There are several ways to use solar energy in buildings. First of all, solar energy can be exploited either passively or actively. In the passive way the energy is introduced without any additional equipment, for example, through windows or by warming up of walls. In the active way the energy is introduced by certain appliances. These active appliances then again are divided into the ones producing heat and the ones producing electricity. (Aurinkovoima 2012, 7-12.)

3.1 Solar collectors

The appliances producing heat are called solar collectors or solar absorbers, and usually their energy is directed into hot water heating. There are some different kind of ways how these collectors work, but the most common applications used in households are a plate collector and a heat pipe system. The plate collector has been popular due to its cheap price but with heat pipes, the efficiency is better (Figures 4 and 5). The most efficient ones have reached fine results but their disadvantage is that their qualities vary quite a lot. Even though they do not require straight sun light, the glass thicknesses are not always enough for the Nordic climate. This fact has to be kept in mind when acquiring a heat pipe system for a house. (Erkkilä 2003, 30-32.)

Figure 4. Solar collector with heat pipes


Figure 5. Heat pipe system with a cover

3.2 Solar panels

The appliances producing electricity are called solar panels (Figure 6). Solar panels consist of solar cells and their working method is different from solar collectors. In the project Ruusutarha solar panels were chosen because the possibilities with them are wider. All the appliances inside the cottage run with electricity, which makes it possible that all of them can work partly with solar power. These appliances include an electric underfloor heating, lighting, a stove, a small fridge, sockets for additional devices, and also a small water heater for a kitchen sink and a shower. A good feature in solar power is that it can be shared with other cottages if there is over production in another one. (Aurinkovoima 2012, 16-17.)

Figure 6. Solar panel array

3.2.1 How solar panels work

Solar panels consist of solar cells, more specifically photovoltaic cells. Photo means light and volt refers to the power unit. Photovoltaic (PV) cells work with the movement of electrons. The first solar panels were invented as early as the 1800s but it was only in the 1950s that they became effective. Then the scientists found a way to make them much stronger.

Electricity that one cell produces is not that much so the cells are combined together under a glass cover forming a module. These modules are usually called panels. The panels can also be joined together and that way they can cover large areas, even the whole roof. The energy that PV cells produce can be charged into a battery, which is useful in the case when the production exceeds the use at a certain moment. The battery enables the usage of electrical appliances when the Sun does not shine anymore.

The PV cell is made of two separate elemental layers. Usually the used element is silicon. The layers are arranged under a glass cover and the layers are treated with chemicals. The other one is treated so that its charging becomes positive and the other one so that it becomes negative. When radiation from the Sun reaches the positive layer, it donates some of its electrons and the negative layer receives them (Figure 7). In that way the electrons are able to move between the two metal plates that are situated at the front and the back parts of the cell. This movement makes electricity flow inside the cell.

PV cells do not require straight sunlight to function. On a sunny day they do produce more electricity than on a cloudy day, but even on a darker day they are able to produce some electricity. In the areas where sunshine is more unlikely, other energy sources might be needed in conjunction with solar power. (Aurinkovoima 2012, 22-24)

Solar cells can be monocrystalline, polycrystalline or amorphous. The working method of all these is similar, and silicon is the most common element used in them. Crystalline silicon cells are 0.2-0.3 mm thick and the surface area of them is (90-160) mm x (120-160) mm. Amorphous cells are flexible and also cheaper, but their efficiency is poorer. (Suntekno)

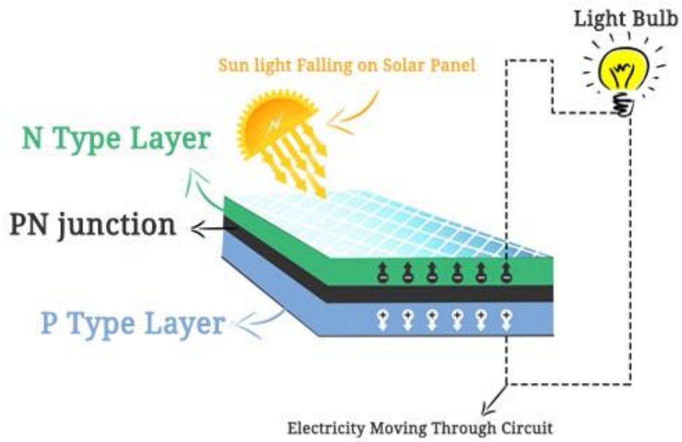

Figure 7. Working method of a regular PV cell http://www.solarpowertoday.com.au/wp-content/uploads/2013/02/solarcell-working-640x320.jpg

3.2.2 Differences between crystalline solar panels

The most common types of solar panels are monocrystalline (Figure 8) and polycrystalline solar panels (Figure 9). Monocrystalline panels have been on the market longer but both of the panels have their own advantages and disadvantages.

Monocrystalline panels consist of solar cells made of monocrystalline silicon ingots, which are cylindrical in shape. For optimizing the performance and lowering the costs of the panels, four sides of the cylindrical ingots are cut to make silicon wafers (Figure 10). Monocrystalline panels are easy to recognize due to these cut corners.

Monocrystalline panels are made out of the highest-grade silicon with a special Czochralski process, which makes the crystal structure uniform. Uniformity reduces recombination and therefore, the panels have the highest efficiency rates. They are also a little more space efficient than other panels which means that with the same area they produce more electricity. Monocrystalline solar panels live the longest and usually they have a warranty of 25 years.

Monocrystalline panels are a little more expensive than polycrystalline panels, and they are also sensitive against coverage. It means that if a part of the panel is covered by shade, dirt or snow, the whole circuit might break down. In addition, the temperature has some impact on the efficiency of the panels. Monocrystalline solar panels tend to be more efficient in the warm weather, but the performance suffers if the temperature gets too high. The issues of temperature are anyhow rather small and regular homeowners do not need to mind about them too much.

Figure 8. Monocrystalline panel http://www.solarinnova.net/images/stories/productos/fotovoltaica/modulos/estandar/monocristalinos/156mm/36/fotos/002-2.jpg

Polycrystalline solar panels are based on polycrystalline silicon that was launched in 1981. In the process of making polycrystalline panel, raw silicon is melted and poured into a square mold, which is then cooled down and cut into square wafers (Figure 10).

Polycrystalline panels are not as efficient as monocrystalline panels, which is due to the lower silicon purity. Their space efficiency is also poorer and they have a slightly lower heat tolerance than monocrystalline panels. Anyway, the process of making polycrystalline panels is easier and it costs less.

It has to be remembered that not all the polycrystalline panels perform worse than monocrystalline panels. There are a lot of manufacturers and all of the panels have little differences in their features. (Energy Informative; Solar Facts and Advice)

Figure 9. Polycrystalline solar panel
http://www.aurinkosahko.net/tuotekuvat/900x600/150wpoly.jpg

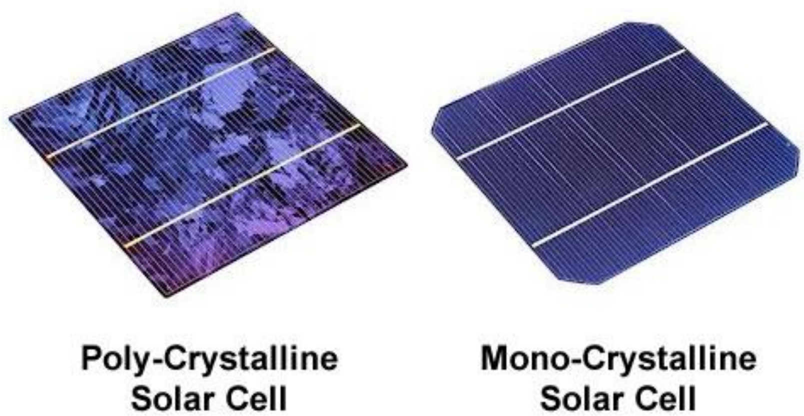

Figure 10. Crystalline solar cells
http://www.siliconsolar.com/wp-content/uploads/mono-v-poly-crystalline-cells.jpg

3.2.3 Why are solar panels worthwhile

Quite often it is thought that the use of active solar energy is not worthwhile here in Finland. The truth is that solar energy could be used a lot more both in heating and electricity production. In southern Finland every square meter receives around 1000 kWh of solar radiation in a year when observing on a horizontal plane. Only during the mid-winter in December and January when the Sun is low, only a little solar energy can be exploited. The problem is that the storing technologies have not developed sufficiently. The amount of radiation changes a lot during the seasons of the year so the storing is an important factor. Even though the technique still has some flaws, individual people can already lighten up their carbon footprints and electricity bills by using straight solar power.

The production of solar energy is based on the amount of sunlight. During the summer time, the amount of solar energy can be even bigger in Finland than in Central Europe (Figure 11). This is due to the fact that the efficiency of many solar panels might even decrease in warmer circumstances.

Traditionally solar energy systems have been used in cases where a regular power grid has not been available. Solar power is a good decision when consumption is little or a power grid is situated far away from the destination. Cottages and boats are common self-contained applications targets. In recent times, grid connected systems have become more and more used. A solar energy system is easy to connect with the regular system. (Aurinkovoima 2012, 24-26)

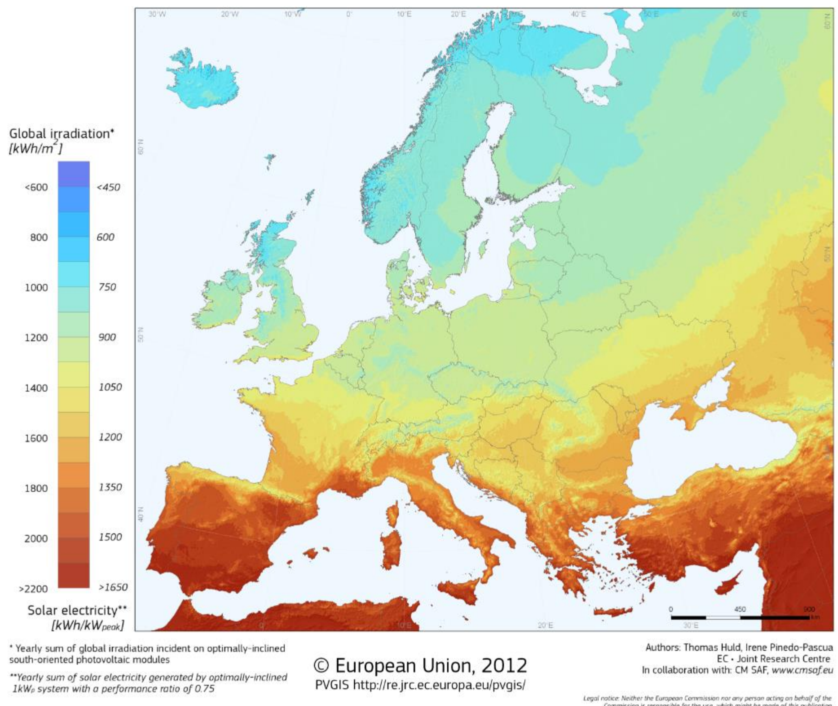

Figure 11. Photovoltaic Solar Electricity potential in European Countries

4 EQUIPMENT NEEDED FOR A SOLAR POWER SYSTEM

For implementing a solar power system, certain equipment is needed. Along solar panels, some other devices are necessary. The electricity that the panels produce is in direct current while the needed form for houses is in an alternating current. To change the current to the correct 230 V alternating current, an inverter is required. Also, the usage of measuring and safety devices are part of the system. The usage of batteries has to be considered depending on the case, too.

Designing a solar power system contains many possibilities and options, and it is not necessarily so straightforward. Some factors delimit the alternative approaches and usage of certain equipment, but decision-making can be challenging.

4.1 Choosing solar panels

In Ruusutarha it was desired that Finnish solar panels would be used if suitable panels were available. There are few companies in Finland producing solar panels, but the company called SaloSolar Oy seemed the most convincing. SaloSolar is the first Finnish company that produces solar panels, and they have been able to make profit unlike some other companies in Finland. It employs 14 people and during one day, they produce approximately 90-100 solar panels. The prices are competitive when comparing to the ones produced in Asia, which makes their viability possible.

SaloSolar produces both monocrystalline and polycrystalline solar panels. The differences between these two types are not radical, and in the case of Ruusutarha either one could be exploited. The monocrystalline panels cost a little more but they also produce more electricity with the same area than with that used for the polycrystalline panels.

Currently the factory of SaloSolar has their production focused on polycrystalline panels. Size of one panel is 1.6 m^2 and it can produce 265 W. The same size monocrystalline panel can produce 280 W, but also the price is a little higher. Using polycrystalline panels could be more convenient in this case.

The length of the panel is 1636 mm and width 992 mm. Its depth is 40 mm and weight 19.3 kg. It has 60 cells in ten rows of six connected in a series (Figure 12). It has a working warranty for 25 years, and it is promised to be free from defects of materials and workmanship for 10 years.

Technical data about the solar panel is needed when suitable inverters are chosen. The most important values for design are the values measured in standard testing conditions (STC) (Figure 13). (SaloSolar)

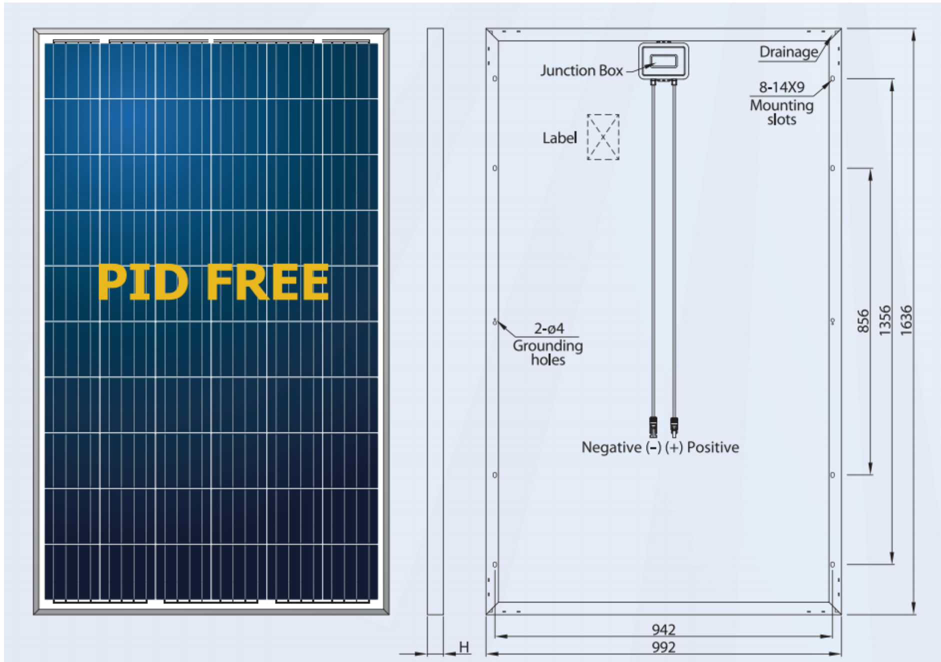

Figure 12. Product image

ELECTRICAL PARAMETERS

TYPE		SS-250W	SS-255W	SS-260W	SS-265W
	Rated Max Power at STC (W)	250,00	255,00	260,00	265,00
STC	Max Power Voltage/Vmp (V)	29,98	30,25	30,51	30,71
AM 1.5,	Max Power Current/Imp (A)	9,34	8,43	8,52	8,63
1000W/m²,	Open Circuit Voltage/Voc (V)	37,41	37,54	37,65	37,81
Module terperature	Short Circuit Current/Isc (A)	8,79	8,94	9,09	9,24
25°C	Modele Efficiency (%)	15,40	15,71	16,02	16,33
NOCT	Rated Max Power at NOCT (W)	180,40	184,1	187,5	191,00
AM 1.5,	Max Power Voltage/Vmp (V)	29,70	27,8	27,90	28,00
800W/m²,	Max Power Current/Imp (A)	6,51	6,62	6,72	6,82
Ambient	Open Circuit Voltage/Voc (V)	34,10	34,2	34,30	34,45
Temperature	Short Circuit Current/Isc (A)	7,11	7,23	7,35	7,47
20°C, Wind	Modele Efficiency (%)	13,89	14,18	14,44	14,71
Speed 1m/s					

Figure 13. Section taken from electrical parameters (SaloSolar)

4.1.1 Size of the panel array

The energy consumption of a house depends on its size. Also, the number of users and their habits have a great impact on the total consumption. The cottages in Ruusutarha are small, and they are meant for a leisure time use. In the best case, the total energy consumption in them can be very low. Even though some of the installations require more power in peaks, the production from solar panels does not necessarily have to cover them. It seems wiser to assemble a smaller array that can take care of the basic consumption, and during the peaks, the regular power grid can cover the rest.

These kind of cottages have not been used yet, so any real experience about the total consumption is not available. To have some sort of an idea about the possible consumption, two different kind of example cases were made (Figure

14). Case 1 presents the usage of a couple that tries to minimize their consumption, and is willing to consider usage of electrical appliances more carefully. Case 2, then again, presents the usage of a family with small children. Especially water consumption in their case is bigger. Also, devices like television will be more in use.

In the calculation, Vattenfall's table about the average consumption of different appliances was utilized. It was a deliberate choice to pick up the lowest values for case 1 and bigger ones for case 2 to highlight the difference between them. The underfloor heating in the main room was left out from the calculation, as its need is minor during the summer time when the full power from solar panels can be utilized. However, the underfloor heating in the wet room, still was included, because it is needed throughout the year. (Sähkölaitteiden keskimääräinen kulutus)

To calculate the water consumption, a hot water heater from Jästi was used as an example. For a couple, a 60-litre tank can be enough, but a family with small children could prefer a tank of 100 litres. Both of the tanks require power of 2 kW, but bigger tanks give more flexibility that is needed in the family. The following formula for the calculation was used:

$$E = P\,t = c\,m\,\Delta T$$

$$\Rightarrow \quad t = c\,m\,\Delta T / P$$

E = Energy required for warming up the water [J]
P = Power of the hot water heater [W]
t = Heating time [s]
c = Specific heat capacity of the heated substance [kJ/kg°C]
m = Mass of the heated substance [kg]
ΔT = Change of temperature due to heating [°C or °K]

c (water) = 4.19 kJ/kg°C
m = 60 kg / 100 kg
ΔT = 80 °C
P = 2000 W

Case 1: t = 4.19 kJ/kg°C * 60 kg * 80 °C / 2000 W = 2.79 h

Case 2: t = 4.19 kJ/kg°C * 100 kg * 80 °C / 2000 W = 4.70 h

For the couple, it could be enough to warm up the tank twice a day. Then the usage time required for hot water heater would be around 6 hours. For the family, also, warming up the tank twice could be enough, but as the tank is bigger, the time required would be around 10 hours.

Devices	Consumption	Usage kWh / day	
		Case 1	Case 2
Fridge 150-200 l	0.3-0.8 kWh / day	0.3	0.8
Freezer 100-200 l	0.5-1.0 kWh / day		1.0
Stove 1 plate	0.5-1.0 kWh / hour	0.5	
Stove 2 plates	1.5-2.0 kWh / hour		2.0
Microwave	0.2 kWh / 10 min	0.2	0.4
Coffee maker	0.1 kWh / 10 min	0.2	0.3
Toaster	0.1 kWh / 10 min		0.1
LCD TV 32" - 37"	0.08-0.19 kWh / hour	0.08 * 2 = 0.16	0.19 * 3 = 0.57
Laptop	0.03 kWh / hour	0.03 * 1 = 0.03	0.03 * 1 = 0.03
Led lighting 3 W	0.003 kWh / hour	0.003 * 3 * 5 h = 0.045	
Led lighting 13 W	0.013 kWh / hour		0.013 * 5 * 7 h = 0.455
Underfloor heating, bathroom	0.285 kW	1.71 (6 h/day)	1.71 (10 h/day)
Hot water heater 60/100 l	2 kW	2 kW * 6 h = 12	2 kW * 10 h = 20
		15.15	27.37

Figure 14 Electricity consumption in cases 1 and 2

When making the decision about the size of the panel array, optimization is important. It seems reasonable to make the decision according to the low consumption, and also, based on estimated power production during the summer time. In Figure 29 in Chapter 7, hours of sunshine are listed. In the summertime, the Sun can shine even around 10 hours per day. In winter time, it only shines 1-3 hours. Basically, any number of solar panels will not produce enough power during the wintertime, so the calculations should not be based on that time of the year.

The optimal number of solar panels for Ruusutarha would be six. With six panels, the maximum production is 1.59 kW. If full production could be received for all those 10 hours, the total consumption would be 15.9 kW. This estimation is optimistic, but it suits well with case 1, which has an estimated total usage of 15.15 kWh a day. It has to be remembered that there is consumption outside of those sunny 10 hours, so it still might be that some of the power produced with solar panels would not go the resident’s own use.

If it is known in advance that the consumption will be a lot higher, and the customer is willing to invest more money in the solar power system, adding extra panels is possible. Adding extra panels later can be done, too.

In addition to production of the panel array, the physical size and weight of it has to be considered. The weight of one panel is 19.3 kg so the whole weight of the array is 55.8 kg. Also, the mounting base raises the total weight. A structural engineer needs to check if some changes are required for the load bearing structures of the cottage. Due to the additional weight, some changes might be necessary.

4.1.2 Placement and mounting of the panels

Solar panels should be assembled near the ridge of the roof not near the eaves where they would work as a snow barrier. The cottages in Ruusutarha have a chimney on the left side of the roof so a suitable place for the panels would be on the right side near the roof ridge (Figure 15). SaloSolar has their own mounting base for installing their panels, and they do not share the information about them. Competition between companies is intense, and for that reason, the assembly drawings are not available. SaloSolar uses their own staff for installations to secure both that the information does not spread that easily, and also that the damages during the assembling can be minimized. (SaloSolar)

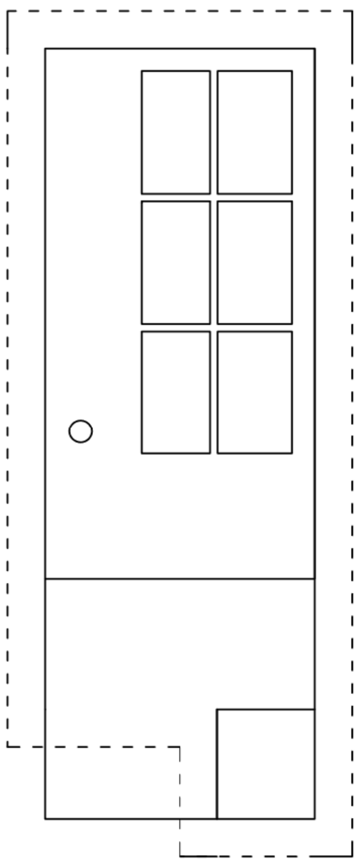

Figure 15. Sketch of the placement of the panels

The mounting angle for the panels can be tricky in Finland. The latitudes make the optimal angle vary between 10-90 degrees from the horizontal plane. Usually the panels are installed at 40-45 degrees because the radiation intensity is the biggest during the summer time when the Sun is also higher. (Finnwind)

4.1.3 Directions of the panels

Directing solar panels in the right way is important. The biggest electricity production is received when the panels are headed to south, but also south-east and southwest are appropriate. When heading the panels straight to east or west, only around 25 % of their maximum production can be achieved. Assembling towards north should not be considered. (Aurinkosähköä kotiin)

The cottages in Ruusutarha only have one roof pane, so the placement of the whole cottage is important. It needs to be checked that both the building is heading a suitable direction and that the slope of the roof is in the right direction. It might be that the original directions have to changed. In that way the panels will reach the sun light the best.

In the site plan it can be seen where the cottages are sketched to be. Most of the locations are workable but there are some which need to be considered again (Figure 16). It has to be observed if the direction of those cottages can be changed or should these cottages be left out without the solar panels.

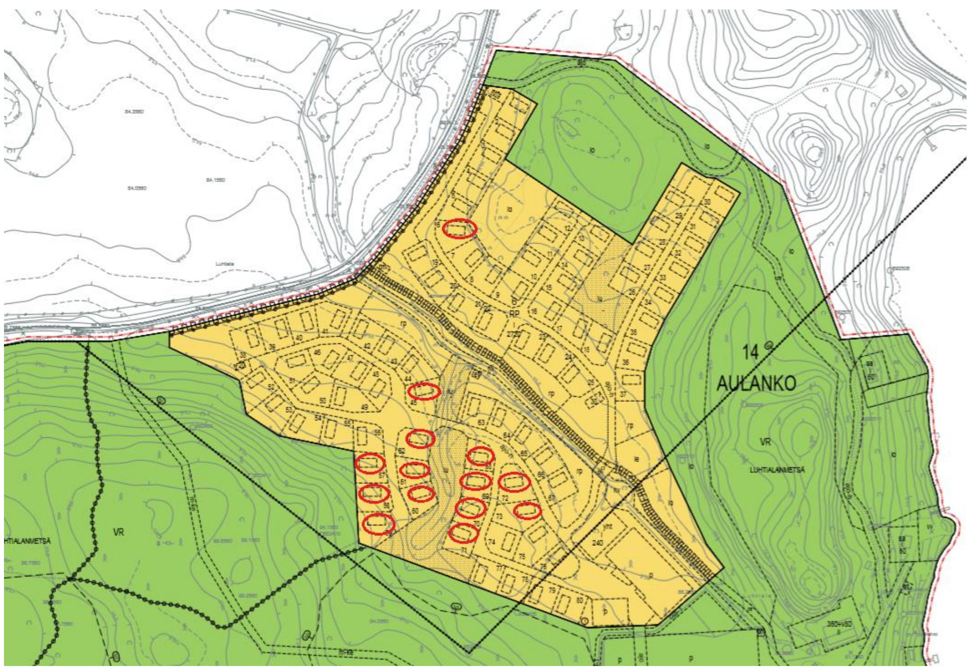

Figure 16. Placement of cottages marked on red need to be considered again

4.2 Current inverters

For a solar power system to function, it requires a current inverter. The task of the inverter is to change the direct current coming from solar panels to alternating current that is used inside the house. An inverter is usually mounted on the wall either inside or outside the house. It is connected between the solar panels and the electricity centre of the house, and so the overproduction can be automatically sold to the electricity supplier.

Usually the cable between the solar panels and inverter should not be longer than 40 m, but even longer distances can be used. A diameter of the cable has to be raised if distances get bigger. In solar power systems, certain double insulated cables suitable for solar power systems have to be used. The correct size is calculated with design software. (Aurinkosähköä Suomeen)

SaloSolar offers certain current inverters with their solar panels, which guided with the selection of the inverters in this project. There are many manufacturers producing different kind of inverters for different kind of cases, so the designer has to be careful.

Selecting an inverter depends greatly on the size of the panel array. In general, a solar power system can either be a single-phase or a three-phase system. In case of Ruusutarha, a regular three-phase system is not an option due to the small size of the panel array. A single-phase system is simpler and it suits best in smaller systems.

In the case of Ruusutarha, a single-phase system could be an option. Single-phase inverters require smaller current coming from the panels for them to start working, and that is their advantage over three-phase inverters. Anyhow, the usage of a three-phase system is usually preferred when the size of the panel array is big enough, because electrical installations are easier to arrange.

In addition to single and three-phase inverters, the usage of micro-inverters is possible. Micro-inverters are utilized in both smaller and bigger systems, and they have their own specific features. The major difference is that each solar panel has their own inverter. In case of Ruusutarha, micro-inverters are a great option due to the small size of the panel array.

4.2.1 Suitable inverters

SaloSolar has created packages with few companies, but inverters from SMA Solar Technology AB seem the best. The range of inverters is large and they have received good feedback from users in Finland. (Aurinkosähköä Suomeen)

SMA Sunny Boy 1.5 (Figure 17) is a single-phase inverter that is claimed to be perfect for customers who want to take full advantage of their small PV system. Using technical data, the suitability with solar panels can be found out (Figure 18). The maximum input it can take is 1.6 kW, which is just enough, as the maximum production for the panel array in Ruusutarha is 1.59 kW. The efficiency of the inverters is 97.2 % and the European weighted efficiency is 96.1 %. The dimension of the inverter is 460 x 357 x 122 mm and it weighs 9.2 kg. If single-phase system was chosen to be used, this inverter would be a suitable choice. (SMA)

Figure 17. SMA Sunny Boy 1.5
http://www.windandsun.co.uk/media/314783/SMA_Sunny_Boy_15_25.png?width=800

Technical Data	Sunny Boy 1.5	Sunny Boy 2.5
Input (DC)		
Max. DC power (at cos φ = 1)	1600 W	2650 W
Max. input voltage	600 V	600 V
MPP voltage range	160 V to 500 V	260 V to 500 V
Rated input voltage	360 V	360 V
Min. input voltage / initial input voltage	50 V / 80 V	50 V / 80 V
Max. input current	10 A	10 A
Max. input current per string	10 A	10 A
Number of independent MPP inputs / strings per MPP input	1 / 1	1 / 1
Output (AC)		
Rated power (at 230 V, 50 Hz)	1500 W	2500 W
Max. apparent AC power	1500 VA	2500 VA
Nominal AC voltage	220 V / 230 V / 240 V	220 V / 230 V / 240 V
Nominal AC voltage range	180 V to 280 V	180 V to 280 V
AC power frequency/range	50 Hz, 60 Hz / −5 Hz to +5 Hz	50 Hz, 60 Hz / −5 Hz to +5 Hz
Rated power frequency/rated grid voltage	50 Hz / 230 V	50 Hz / 230 V
Max. output current	7 A	11 A
Power factor at rated power	1	1
Adjustable displacement power factor	0.8 overexcited to 0.8 underexcited	
Feed-in phases/connection phases	1 / 1	1 / 1
Efficiency		
Max. efficiency / European weighted efficiency	97.2 % / 96.1 %	97.2 % / 96.7 %
Protective Devices		
DC-side disconnection point	●	●
Ground fault monitoring / grid monitoring	● / ●	● / ●
DC reverse polarity protection / AC short-circuit current capability / galvanically isolated	● / ● / –	● / ● / –
All-pole sensitive residual-current monitoring unit	●	●
Protection class (according to IEC 62103) / overvoltage category (according to IEC 60664-1)	I / III	I / III
Reverse current protection	Not required	Not required
General Data		
Dimensions (W / H / D)	460 / 357 / 122 mm (18.1 / 14.1 / 4.8 inches)	
Weight	9.2 kg (20.3 lbs)	
Operating temperature range	−40 °C to +60 °C (−40 °F to +140 °F)	
Noise emission, typical	<25 dB	<25 dB
Self-consumption (at night)	2.0 W	2.0 W
Topology	Transformerless	Transformerless
Cooling method	Convection	Convection
Degree of protection (according to IEC 60529)	IP65	IP65
Climatic category (according to IEC 60721-3-4)	4K4H	4K4H
Maximum permissible value for relative humidity (non-condensing)	100 %	100 %
Features		
DC connection / AC connection	SUNCLIX / connector	SUNCLIX / connector
Display	–	–
Interfaces: RS485, *Bluetooth*®, Speedwire / Webconnect, WLAN	– / – / ● / ●	– / – / ● / ●
Integrated web server	●	●
Warranty: 5 / 10 / 15 / 20 / 25 years	● / ○ / ○ / ○ / ○	● / ○ / ○ / ○ / ○
Certificates and approvals (others available upon request)	AS4777.3, C10/11/2012, CEI0-21Int, EN50438, G83/2, IEC61727, IEC62116, IEC62109, NBR16149, NEN-EN50438, NRS097-2-1, VDE-AR-N4105, VDE 0126-1-1, VFR2014	
Type designation	SB 1.5-1VL-40	SB 2.5-1VL-40

Figure 18. Section taken from Technical Data Sheet (SMA)

The smallest three-phase inverter from SMA is called SMA Sunny Tripower 5000 TL (Figure 19). Going through technical data shows that its minimum input voltage is 150 V and the minimum start input voltage is 188 V (Figure 20). The maximum power voltage that one chosen panel from SaloSolar can give is 30.71 V. It means that even the total power voltage of 184.26 V would not be enough for the inverter to start working. The advantage over a three-phase inverter is that electrical plans do not have to be considered that much. For that reason, three-phase systems are preferred in cases where the panel array is big enough. (SMA)

Figure 19. SMA Sunny Tripower 5000 TL
http://www.sma.de/uploads/tx_lwsmaproducts/tripower5-9k_01.png

Technical Data	Sunny Tripower 5000TL	Sunny Tripower 6000TL
Input (DC)		
Max. DC power (@ cos ϕ = 1)	5100 W	6125 W
Max. input voltage	1000 V	1000 V
MPP voltage range / rated input voltage	245 V ... 800 V/580 V	295 V ... 800 V/580 V
Min. input voltage / start input voltage	150 V / 188 V	150 V / 188 V
Max. input current input A / input B	11 A / 10 A	11 A / 10 A
Max. input current per string input A / input B	11 A / 10 A	11 A / 10 A
Number of independent MPP inputs / strings per MPP input	2 / A:2; B:2	2 / A:2; B:2
Output (AC)		
Rated power (@ 230 V, 50 Hz)	5000 W	6000 W
Max. AC apparent power	5000 VA	6000 VA
Nominal AC voltage	3 / N / PE; 220 / 380 V 3 / N / PE; 230 / 400 V 3 / N / PE; 240 / 415 V	3 / N / PE; 220 / 380 V 3 / N / PE; 230 / 400 V 3 / N / PE; 240 / 415 V
Nominal AC voltage range	160 ... 280 V	160 V ... 280 V
AC grid frequency / range	50 Hz, 60 Hz / -5 Hz ... +5 Hz	50 Hz, 60 Hz / -5 Hz ... +5 Hz
Rated power frequency / rated grid voltage	50 Hz / 230 V	50 Hz / 230 V
Max. output current	7.3 A	8.7 A
Power factor at rated power	1	1
Adjustable displacement power factor	0.8 overexcited ... 0.8 underexcited	0.8 overexcited ... 0.8 underexcited
Feed-in phases / connection phases	3 / 3	3 / 3
Efficiency		
Max. efficiency / European efficiency	98 % / 97.1 %	98 % / 97.4 %
Protective devices		
DC disconnect device	●	●
Ground fault monitoring / grid monitoring	● / ●	● / ●
DC reverse polarity protection / AC short-circuit current capability / galvanically isolated	● / ● / –	● / ● / –
All-pole sensitive residual-current monitoring unit	●	●
Protection class (according to IEC 62103)/overvoltage category (according to IEC 60664-1)	I / III	I / III
General data		
Dimensions (W / H / D)	470 / 730 / 240 mm (18.5 / 28.7 / 9.5 inch)	470 / 730 / 240 mm (18.5 / 28.7 / 9.5 inch)
Weight	37 kg (81.6 lb)	37 kg (81.6 lb)
Operating temperature range	-25 °C ... +60 °C (-13 °F ... +140 °F)	-25 °C ... +60 °C (-13 °F ... +140 °F)
Noise emission (typical)	40 dB(A)	40 dB(A)
Self-consumption (at night)	1 W	1 W
Topology / cooling concept	Transformerless / Opticool	Transformerless / Opticool
Degree of protection (according to IEC 60529)	IP65	IP65
Climatic category (according to IEC 60721-3-4)	4K4H	4K4H
Maximum permissible value for relative humidity (non-condensing)	100 %	100 %
Features		
DC connection / AC connection	SUNCLIX / spring-cage terminal	SUNCLIX / spring-cage terminal
Display	Graphic	Graphic
Interface: RS485, Bluetooth, Speedwire / Webconnect	○ / ● / ●	○ / ● / ●
Multifunction relay / Power Control Module	● / ○	● / ○
Guarantee: 5 / 10 / 15 / 20 / 25 years	● / ○ / ○ / ○ / ○	● / ○ / ○ / ○ / ○
Certificates and permits (more available on request)	AS 4777, CE, CEI 0-21[3], C10/11:2012, DIN EN 62109-1, EN 50438[1], G59/3, G83/2, IEC 61727/MEA[2], IEC 61727/PEA[2], IEC 62109-2, NEN EN 50438, NRS 097-2-1, PPC, PPDS, RD 661/2007, RD 1699:2011, SI 4777, UTE C15-712-1, VDE0126-1-1, VDE AR-N 4105, VFR 2013, VFR 2014	
Type designation	STP 5000TL-20	STP 6000TL-20

Figure 20. Section taken from Technical Data Sheet (SMA)

SMA Sunny Boy 240 is a micro-inverter from SMA (Figure 21). Unlike regular string inverters, micro-inverters are used with each solar panel, not only one inverter per system. When using micro-inverters, it has to be ensured that chosen solar panel is not too big for them. Again, technical data about the device is needed (Figure 22). Its maximum power at standard testing conditions (STC) is 300 W, which suits well with the chosen 265 W panel. Both voltages at the maximum power and maximum DC short-circuit current at STC are within the limits. With micro-inverters it is possible to create a system that supplies all the three phases like with a regular three-phase inverter. The maximum efficiency of SMA Sunny Boy 240 is 95.8 % and the European weighted efficiency is 95.3 %, so the efficiency is a little lower than with the single-phase inverter.

Figure 21. SMA Sunny Boy 240
https://ww3.wholesalesolar.com/inverter_folder/Sunny-Boy-240-US-small.jpg

Recommended photovoltaic modules
Max. power at STC 300 W
Voltage at max. power at STC 26 V to 32 V
Max. DC short-circuit current at STC 12 A

Technical Data	Sunny Boy 240	Sunny Multigate
Input (DC)		
Max. input voltage	45 V	–
MPP voltage range / rated input voltage	23 V - 39 V / 29.5 V	–
Min. input voltage / max. initial input voltage	23 V / 40 V	–
Max. input current	8.5 A	–
Max. number of micro inverters	–	12 x SB 240-10
Output (AC)		
Rated power (at 230 V, 50 Hz)	230 W	2760 W
Max. apparent AC power	230 VA	2760 VA
Nominal AC voltage / range	230 V / 184 V - 270 V	230 V / 184 V - 270 V
AC power frequency / range	50 Hz / 45.5 Hz to 63 Hz	50 Hz / 45.5 Hz to 63 Hz
Rated power frequency / rated grid voltage	50 Hz / 230 V	50 Hz / 230 V
Max. output current	1 A	12 A
Power factor at rated power	1	1
Feed-in phases / connection phases	1 / 1	1 / 1
Efficiency		
Max. efficiency / European efficiency	95.8% / 95.3%	–
Protective Devices		
Ground fault monitoring / grid monitoring	● / ●	– / ●
DC reverse polarity protection / AC short-circuit current capability / galvanically isolated	● / ● / ●	– / ● / –
General Data		
Dimensions (W / H / D)	188 / 218 / 44 mm (7.4 / 8.6 / 1.7 inch)	162 / 90 / 68 mm (6.4 / 3.5 / 2.5 inch)
Weight	1.3 kg (2.9 lb)	0.75 kg (1.5 lb)
Operating temperature range	-40 °to +65 °C (-40 °to +149 °F)	-40 °to +45 °C (-40 °to +113 °F)
Noise emission	< 38 dB(A)	–
Self-consumption (at night)	< 0.03 W	–
Topology	HF transformer	–
Cooling method	Convection	Convection
Degree of protection (according to IEC 60529)	IP65	IP20
Max. permissible value for relative humidity (non-condensing)	100%	–

Figure 22. Section taken from Technical Data Sheet (SMA)

4.3 Usage of batteries

Including batteries in the solar power system is not clear. In autonomous systems, it is necessary to have batteries if it is wanted that electrical appliances like lighting can also be used during the dark time of the day. In the systems where solar panels are attached to a regular power grid, the case is not so simple. In case of Ruusutarha, especially storing electricity within the whole community seems interesting. The battery technology still has some flaws but the subject is studied and there are companies working on the new technology. (Motiva)

4.3.1 Self-contained systems

In self-contained solar power systems, the usage of batteries is necessary. Battery technology is rather expensive in comparison with the power received, but in autonomous systems, it basically is the only option.

The decision about suitable battery depends on the usage. If the cottage is used rarely, it is wiser to invest in a bigger battery and save in purchasing less solar panels. The idea is that the battery will be charged during the time that is spent away from the cottage. If the consumption is evenly distributed by the whole week, smaller batteries can be used.

If the same kind of small battery systems were desired to be used in cottages in Ruusutarha, the packages would have to be designed separately for each household. The amount of consumption, duration of the stay and evenness of the use are factors having an impact on the size and type of the needed battery system. Batteries using AGM (Absorbed Glass Mat) technique are suitable for solar power systems, and with them small consumption, like lighting, could be taken care of. Only the basic devices utilize the voltage that the batteries can offer, and for that reason, possibilities for different devices in autonomous systems are limited. Not all the equipment inside the cottage could be exploited with the power taken from the battery.

The difficulty in storing power is that the alternating current cannot be stored. Both inverters and converters are needed in the process. When using a regular string inverter, batteries can be placed right after the panel array, and a converter is not needed, but with micro-inverters the system becomes complex.

The batteries used in self-contained systems have traditionally been lead-acid batteries. The new battery technology prefers lithium, and it is slowly breaking through. (Pellettipojat; SW Energia)

4.3.2 New battery technology

The problem with solar power systems is that the storing possibilities are not efficient enough. The technology has been progressing, and the hope is that soon it will reach the markets. In spring 2015, Tesla Motors launched a lithium-ion battery called Powerwall (Figure 23). It is a battery that can be charged by solar power, and it works as a power storage at homes. The product is not yet available, but pre-orders can be made. If the battery works the way it is claimed to work, it may solve many problems. With a system like that, the overproduction could be stored for the time when it is needed, instead of selling it to the power supplier. (HS)

Figure 23. Tesla Powerwall
http://assets.inhabitat.com/wp-content/blogs.dir/1/files/2015/05/tesla-powerwall-battery-mounted-outside1.jpg

SMA keeps up with the new technology, as some time ago it started to offer battery inverters that are compatible with high-voltage batteries from all reputable manufacturers, like Tekla Motors. SMA Sunny Boy Storage 2.5 can be used with both new and existing systems, and investing in it could be worth it if retrofitting of the new battery technology is desired.

SMA also has another product representing new technology. Sunny Boy 3600 Smart Energy, is an inverter that has a combined lithium-ion battery in the same (Figure 24). Integrations like this are rarely offered. The minimum input voltage of this inverter is 125 V, which is too high for the system in Ruusutarha, but this kind of storing possibility can be worth it even in the systems that are joined together with the regular power grid. The storing capacity of the battery is 2.0 kWh and installation does not require any extra consideration. The battery used in the system is from LG Chem. (SMA)

Figure 24. SMA inverter with combined lithium-ion battery
http://www.sma.de/fileadmin/content/global/Products/Images/Wechselrichter_ohne_Trafo/sb_smartenergy/SB3600_5000_smart_energy.png

5 PLANS FOR ASSEMBLING

Assembling a solar power system can be made in many different ways. After deciding the size of the panel array, the matters about power supply appear. After that, it has to be considered what kind of changes are required for the original electrical plans. Decisions about storing the power and power usage within a community also have to be discussed.

5.1 System size

The cottages in Ruusutarha have all the modern equipment that a regular house has. It means that the need for electricity will be high if all the equipment is used at the same time. The panels themselves will not be enough to cover the need during that kind of a peak. Anyway, it can be expected that these cottages will be used the most during the summer time, when especially the need for heating is not that high. Also, it is likely that most of the time will be spent outside either in the garden or in some other leisure activities. The idea is that during the low need of electricity, the panels could cover the whole need of power and during the higher need it could support the regular electricity grid.

It might seem silly not to cover the whole sunny side of the roof with solar panels, but only assemble few of them. In Ruusutarha the chosen six panels would only cover around one third of the surface area. The fear is that during the sunny time, a lot of overproduction might be generated. Due to poor storing possibilities, the overproduction would have to be directed to the electricity supplier's grid. The method is working, but optimizing the array size also reduces the start-up costs. The case in Ruusutarha differs from a regular house because the consumption can be really small. Assembling a bigger panel array would only be wise if it could be stored for habitant's own use.

5.2 Power supply

The solar power system can either be a single-phase or a three-phase system. In practice, it means that either only one or all the three of the electrical phases can be supplied with the electricity received from solar panels. When it is about a smaller solar power system like in Ruusutarha, a single-phase system could be easier to implement. Anyhow, the single-phase system has its own flaws and for that reason the possibility of having a three-phase system needs to be considered more specifically.

5.2.1 Single-phase system

When making the electricity plans, it has to be chosen which electrical equipment is runs on each phase. The plans are made so that all the three phases are as equally loaded as possible. The balance between the three phases is important due to electro technical reasons. When using a solar power system with a single-phase inverter, only one of the three phases can be supplied with the generated solar power (Figure 25). It means that only if equipment is used during the sunny time, the power can be utilized. So, even if the usage was small, it could be that the power had to be taken from regular grid instead of the panels. Due to the shared power grid, this electricity could anyway, be utilized in some other cottage, where that certain phase was in need of power.

If it was decided to use a single-phase system in Ruusutarha, also the balance between the cottages has to be ensured. That would mean that in every third cottage the solar power has to be connected with phase one, in every third with phase two and every third with phase three. In that way it could be made sure that the power grid is loaded evenly.

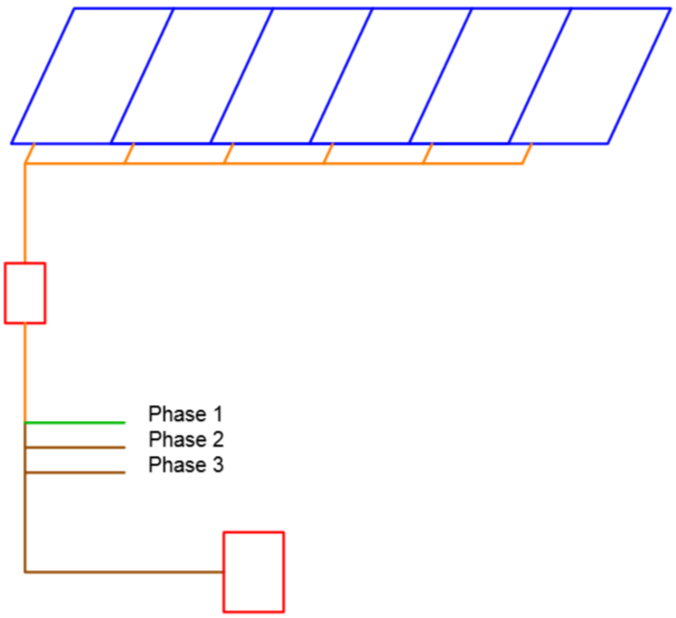

Figure 25. Single-phase system; One of the phases can be supplied with solar power, and other two are only supplied with electricity from grid

5.2.2 Three-phase system

The good thing about a single-phase system is that the inverter does not require as high current as a three-phase system for it to start working. It means that even in the cloudy weather some of the solar energy can be put into use. From here we get to the three-phase system (Figure 26). A three-phase system is more convenient what comes to electrical plans but for proper functioning it requires a higher current. In case like Ruusutarha, the surface area of the solar array is rather small as well as the maximum output. In reality, it would mean that the solar power could be only utilized during very bright and sunny day. At all the other times the panels would not be used.

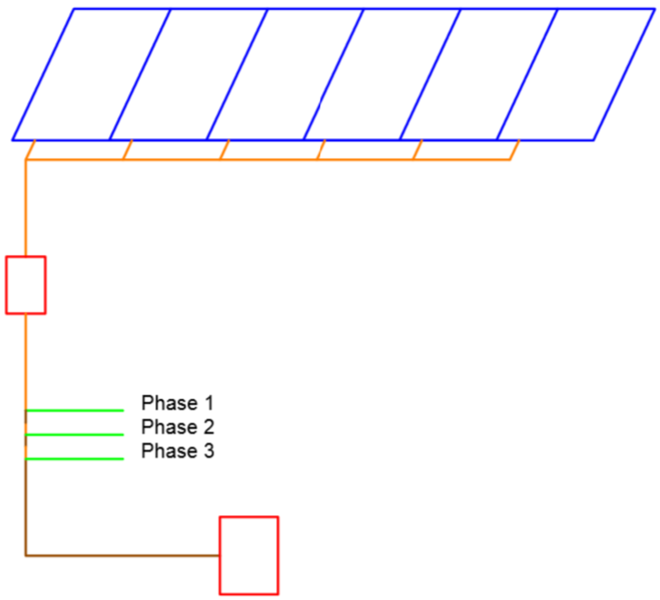

Figure 26. Three-phase system; All three phases can be supplied with solar power but are supported with electricity from grid if production is not enough

5.2.3 Three-phase system with micro-inverters

There is also a third way to arrange a solar power system. It takes place with micro inverters. With micro inverters, it is possible to make a system that supplies all the three phases. The panels can be divided into three groups each supplying one phase. In case of Ruusutarha, there are six panels that can be paired up, and in that way three groups are enabled (Figure 27). The disadvantage is that the efficiency is of micro inverters is not as high as with regular inverters but the needed current is not as high either. With micro inverters the good features of three-phase system can be achieved even when the size of the array would suit better with a one-phase system.

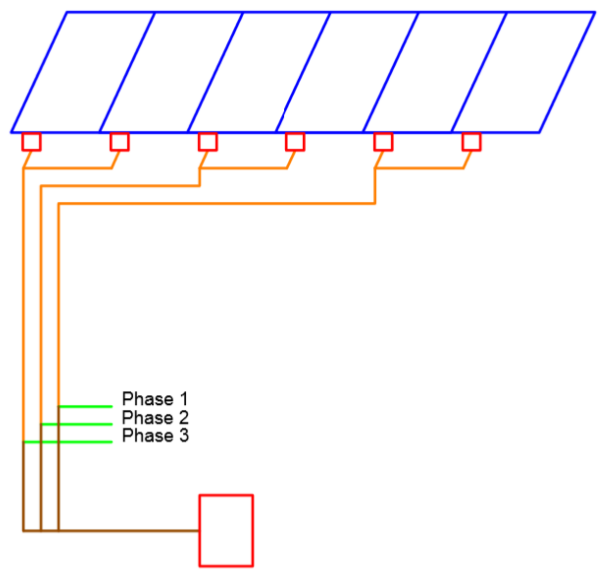

Figure 27. Three-phase system made with micro-inverters; Alternative for a regular three-phase system

5.3 Electrical plans

The cottages in Ruusutarha allotment gardening were originally designed without solar panels. Solar panels will not necessarily make any changes to the electrical plans but some notices can be made.

5.3.1 Electricity consumption

When the system runs with solar power, it is usually wanted that the total consumption of electricity is minimized, so that the need for electricity from the regular power grid could be best avoided.

The usage of low voltage lighting, like led-lighting, is a simple choice. There are two types of low voltage lighting; others require a special low voltage circuit but the other ones can be attached to a regular circuit. The ones that can be attached to a regular circuit have their own small converters built-in but their efficiency is not as good as with the other ones.

Another notice about the electrical plan is that it is missing a hot water heater. A small hot water heater the size of 60 litres is a single-phase device and can be plugged into a regular socket. A suitable place for it would be in the hall-way in the cabinet. A reservation for it has to be included in the electricity plans.

If the total consumption of electricity is wanted to be minimized, electricity consumption of all the devices should be observed more closely, and also a prudent usage should be favoured.

If a cottage owner is more interested in sustainable energy, adding solar collectors could also be possible. The usage of solar collectors cannot really be exploited as a community, but in individual cottages this kind of arrangement could be possible. If only six solar panels are installed on the roof, there is some area left for the collectors.

5.3.2 Automation

By using control systems together with electrical automation, the power received from solar panels can be used more wisely. For example, by using clocks, the automation can direct solar power into certain devices at certain times. It could be wise to have underfloor heating of the main area switched on at the time that is assumed to be sunny. The temperature would most probably drop during the night time, but it could be ensured that if the temperature gets too low, the heating would turn on even though it was not the sunny time. Also, the usage of sun sensors is possible.

The more moving parts the system has, the more residents should know about its working methods. This would enable a full advantage of the system.

5.4 Power storage

Storing the power produced with solar panels is important in autonomous systems, where the regular power grid is not present. Usually, the usage of batteries in the joined systems is not preferred. In the case of Ruusutarha, a shared power grid would enable utilizing over production of one cottage in another one, so the usage of batteries seems unnecessary. Investing in a bigger battery, which could be exploited together among the whole allotment community, seems the only reasonable option. If over production was generated, and none of the cottages were in the need at the time, the production could be directed into the battery. This kind of system, anyhow, requires more components as the current stored in batteries are in direct current. All these components consume part of the power and the final amount of power diminishes.

Using one bigger battery does not exclude the usage of micro-inverters, as with a bigger system the usage of more components is more sensible. If converters had to be placed in each cottage, prices would rise so high that the investment would not be worth it.

Battery technology is advancing all the time, but finding a reasonable battery is difficult, or at least expensive. Also, the benefits achieved are questionable. Selling the overproduction back to the electricity supplier is nowadays possible, so the power is never really wasted. Transforming the power back and forth between the devices and batteries then again would consume extra power.

In larger complexes like factories, the usage of batteries could be worth the investment. There the consumption is higher and thereby the costs, too.

5.5 Common grid

The idea behind a common power grid is great when a community wants to take the most out of their solar power systems. This kind of action where the power grid is shared, some arrangements are required. The case is that the housing association in Ruusutarha would have to found a company working for it and officially take care of the matters. In practice, this could be organized so that a customer buying a cottage would at the same buy a share from the company.

The company would buy all the electricity used in cottages from the electricity supplier, and it would handle the whole grid. All the cottages would have a two-way measuring for the electricity transportation. That enables keeping track of how much electricity is taken from the regular power grid.

6 PERMIT WORK

When assembling a solar power system, some compulsory permit work is included. In some municipalities, applying for a building permit is required, but mostly it is enough if the municipality is informed about the change in the façade. When attaching the solar power system to the regular power grid, both the network and electricity suppliers need to be contacted. Also, applying for energy subsidies is a thing that can be considered.

6.1 Building inspection

In some municipalities, it is still required to apply for a building permit to get a permission to install solar panels. Mostly, like in Hämeenlinna, it is enough only to give a notification about the measure. The municipality might ask for some more detailed information, but basically it is only a formality. The installation changes the façade of a building, and for that reason it has to be informed. In the case of Ruusutarha, it is about a new construction, so separate act is not needed. If the solar panels are installed later, this kind of announcement has to be made. (Finnwind)

6.2 Network and electricity companies

Power production with solar panels is usually classified as micro-generation. The limitation for micro-generation is 50 kVA and for a small-scale production, it is 100 kVA. All the production under 100 kVA is free from taxing. Also, if the annual production is less than 800000 kWh, taxes are not charged. (Tuotannon taulukko)

If all the 80 cottages in Ruusutarha had the panel array the size of 1.59 kW, and all of the panels were producing their maximum at the same time, the total production would be 127.2 kW, which in this case means the same as 127.2 kVA. In reality, achieving this kind of production is hardly possible. Even if the upper limit of 100 kVA was exceeded for a short while, the yearly production could be still fallen short, and the notification for the tax authorities would not have to be made.

In Finland, the companies taking care of the electricity grid are separated from the companies selling the electricity itself. The network companies take care of the power grids and transfer the electricity. The electricity companies, then again, make the sales of the electricity itself. Attaching micro-generation to a regular power grid has to be discussed with the network company. The network company taking care of the power grid has to be contacted well in advance so that all the needed planning and possible alterations can be done in time.

All design work including the main diagram, protection, control and grounding diagrams and residual current calculations need to be delivered to the company, as well as the general technical information. Assembling needs to be done by specialists and the used equipment needs to be certified.

The network company requires that the solar power system has to be equipped with safety devices that can automatically switch off the system from the regular power grid at a time of power cut. Also, if the frequency or the voltage of the grid are not right for the system, it has to be able to switch off automatically. (Lehto 2009)

Outside the building, there has to be a safety switch for the network company (Figure 28). In case of maintenance work, there has to be a way for the network company to switch off the power coming from the solar power system to the regular power grid.

For the electricity company, a two-way meter has to be installed. Usually it is mounted inside the main centre outside the house, where the electricity is bought. There it can be monitored how much electricity is bought and sold. (Aurinkovirta)

Figure 28. One type of safety switch situating outside the building

6.3 Energy subsidies

The Ministry of Employment and the Economy can grant subsidies for certain projects that are favourable towards climate and the environment. The energy subsidies are specially meant to promote the introduction of new technologies and getting them on the market. These subsidies are granted for companies, municipalities and communities.

If the residents in Ruusutarha are going to form a community in order to share the power grid, applying for the grant is also possible. Typically, the amount of the grant in projects using solar power is about 30 % of the budget. Any-how, in 2013 the processing limit was raised to five million euros, and that might prevent the granting in the case of Ruusutarha. A project similar to Ruusutarha only a little bigger could easily exceed the limit. (Energiatuki; Energiatuki uudistuu)

7 PAYBACK TIME

The usage of solar power is a green choice. That itself makes the acquisition reasoned. Anyway, people are interested in the money, and installing a solar power system is an investment. People want to know how fast the system can pay itself back and start earning money. With solar power, the case often is not so easy to estimate.

7.1 Costs

Installing a new solar power system is rather expensive. The good thing is that the start-up, basically, is the only phase when any costs are generated. The system is maintenance-free, and after the installation it should work years without any extra costs. Occasional sweeping of pollen or other dust might be needed, but that can be enough even for the first 25 years.

Solar panels from SaloSolar have 10 years of warranty for the defects of materials and workmanship, and they grant that the efficiency will not decrease more than 3.72 % during the first 25 years. Inverters from SMA, then again, have a manufacturer’s warranty of 5 years, but it can be prolonged with SMA Extended Warranty until 25 years in periods of 5 years. Basically, the money spent at the time of purchase can carry for 25 years. (SaloSolar; SMA)

7.1.1 Devices

SaloSolar sells a package similar to the wanted for Ruusutarha with 2978 €. The package includes six of monocrystalline solar panels the size of 280 W, SMA Sunny Boy 1.5 and all the necessary mounting equipment. Monocrystalline solar panels are more expensive to manufacture, which means that the package should be a little cheaper with the wanted polycrystalline panels. (Hinnasto 2016 Areva Solar)

According to the retailers, SMA Sunny Boy 1.5 costs around 580 €, and SMA Sunny Boy 240 around 180 €. All together, the needed micro-inverters would cost around 900 €, which means that the price of the system would be approximately 320 € more expensive with them than with SMA Sunny Boy 1.5.

In the case of Ruusutarha, the contract would be made for many cottages, possibly even for 80, so the actual price for one system can be expected to be less than the one given. Any tender has not been made yet, so the true figures cannot be provided.

As a comparison, Vattenfall offers the same kind of package with European solar panels with the price of 4200 €. The package includes all the costs from the materials to installations, and the required paper work when installing the system and connecting it to the regular power grid. When comparing this offer to the one from SaloSolar, approximately 1000 € can be left for installation and paper work, and still the package would not be more expensive. It seems that the usage of Finnish solar panel can be profitable. (Aurinkopaneelit taloon)

7.1.2 Installations

Installation of the solar power system has to be made by a specialist. SaloSolar requires to use their own technicians, so the installation would have to be included in the contract.

In addition to the installation of the panel array, also additional work required from the network company might increase the costs a little. In the case of Ruusutarha, the connection to the electricity grid is anyway new, so the needed installation work can be done at the same time. (Sähkön tuotanto)

7.2 Savings

When producing electricity with a solar power system, the need for electricity from the regular power grid, stops totally or partly. After the start-up costs, the produced power, basically, is free. The electricity that is produced with the solar power system, automatically reduces the fees to the both network and electricity company. If overproduction is generated, even profit can be made.

7.2.1 Amount of production

The Meteorological Department in Finland has made a report about the weather in Finland in the years 1981-2010. The report includes the hours that the Sun was shining. One of the measuring points situated in Helsinki-Vantaa airport, and it is the closest one to Ruusutarha. The average amount of the hours of sunshine during one year was 1780 h (Figure 29). (Tilastoja Suomen ilmastosta)

Auringonpaistetunnit
Duration of sunshine

Kk Month	Karvo Mean	Absol ylin/max	V/Year	Absol alin/min	V/Year
1	JOMALA MAARIANHAMINA LENTOASEMA				
1	39	67	1987	2	1988
2	74	139	1983	21	1988
3	130	187	2000	62	1988
4	207	290	2005	103	1983
5	297	363	2002	214	2005
6	296	366	2006	169	1987
7	312	441	1994	199	2000
8	235	345	2002	155	1986
9	163	242	2000	95	1984
10	91	126	1985	59	2000
11	41	70	1983	14	2009
12	26	56	1995	9	1997
Vuosi/ Year	1911	441		2	
2	PARAINEN UTÖ				
1	39	70	1997	8	1988
2	66	116	1986	22	1988
3	138	224	2005	71	1992
4	211	295	2002	100	1983
5	309	396	1999	210	1983
6	308	385	2006	192	1987
7	321	433	1994	228	2000
8	259	365	2002	170	1987
9	179	271	2000	99	1984
10	95	134	2005	62	2007
11	39	74	1983	10	2009
12	26	58	1988	3	1984
Vuosi/ Year	1990	433		3	
301	VANTAA HELSINKI-VANTAAN LENTOASEMA				
1	38	77	1987	14	2001
2	74	155	1994	38	1990
3	131	219	2005	35	1992
4	196	289	2004	94	1992
5	275	351	2002	182	1987
6	266	350	1992	187	1981
7	291	405	1994	210	1984
8	219	342	1997	108	2008
9	143	234	2000	60	1984
10	84	123	2005	31	2006
11	37	79	1988	12	2000
12	26	49	1995	6	1984
Vuosi/ Year	1780	405		6	

Figure 29. Section taken from the report showing the hours of sunshine

If the panel array could give its full power of 1.59 kW for an entire hour during all those 1780 hours, the production would be 2830.2 kWh. Vattenfall estimates that a system similar to the one in Ruusutarha, would produce 1400 kWh in a year, which is more realistic. (Vattenfall)

7.2.2 Amount of consumption

The consumption of one cottage, then again, is even more difficult to estimate. Even though the level of equipment inside the cottages is quite the same, the differences in consumption can be extensive due to different habits in usage. If the cottage is used throughout the year, the consumption will also be a lot higher. Lighting and devices, surely, require electricity but especially the heating consumes plenty of it. If the cottage is out of use during the winter period, the temperature can be set lower, and not that much electricity is used.

The Ministry of Environment and the Economy made a statement about the usage of electricity in households in Finland. According to it, a regular apartment house with one habitant consumes 1400 kWh per year, and for three inhabitants the amount is 2400 kWh. A regular detached house of the size 120 m^2 with a regular level of equipment and two inhabitants, then again, consumes 17400 kWh when the house is heated with electricity. Heating is done with electric radiators, and it takes 63 % of the total consumption. With four inhabitants, the consumption is 19600 kWh but only 49 % goes to heating. In a house with two inhabitants, 1400 kWh more is used in heating.

In the study, underfloor heating was included in the high level of equipment, and it was used together with district heat. Anyway, these values give a rough idea about the total consumption in residential houses. Cottages in Ruusutarha only have 25 m^2, which means that the heating should not take as much as in the examples. Also, the absence of sauna reduces the total electricity consumption, as well as the fact that everyday chores like doing laundry are not part of the life at the cottage to the same extent. (Kotitalouksien sähkönkäyttö)

Even though the consumption in cottages in Ruusutarha is presumably higher than in traditional summer houses, the small size and lower usage decreases the total consumption down from a regular detached house. If the sizes are directly compared, the consumption in the cottage would be approximately one fifth of the one in a regular detached house, which is around 3500-4000 kWh. In such a case, the production with solar panels could cover one third of the total consumption.

7.2.3 Savings in electricity

Electricity can be bought from any seller, and it can be put out to tender. Companies make different kind of deals depending on how the electricity has been produced. Vattenfall offers a regular contract with 3.92 cent/kWh for the energy, and 1.20 €/year for the basic fee. If the total production of the panel array is 1400 kWh in a year as can be estimated, savings in electricity are 56.08 in a year.

If overproduction is generated at a certain moment, it can be sold to the electricity company. The contracts are made separately in each case. In Vattenfall, the same market price is paid. For the producer, it is more profitable if all the production can be used by himself, as the transfer costs are not included in it. (Vattenfall sähkösopimusten vertailu)

7.2.4 Savings in transfer and taxation

When using electricity from the regular power grid, in addition to paying for the electricity itself, one has to pay for the transfer, too. Network company takes care of the transfer, and it cannot be put out to tender, because the company has been determined regionally. In Ruusutarha, the network company is Elenia.

Elenia has different kind of deals for the transfer, but the common one costs 3.95 cent/kWh before taxing. If the customer belongs to a tax class 1, the price is 6.74 cent/kWh. In addition to this, a basic fee is charged according to the size of the main fuse.

If the total production of the panel array is 1400 kWh in a year, savings in transfer and its taxation are 95 €. Together with the savings in electricity, the total amount is 150 € in a year. (Elenia)

7.3 Possible subsidies

If the Ministry of Employment and the Economy grants the energy subsidies for Ruusutarha, even 30 % of the start-up costs can be reduced. In such projects where most of the costs are generated during the establishment, this kind of support is a huge advantage.

7.4 Overview

In 25 years, which is the warranty period for the system, 3761 € can be saved, assuming that the production efficiency and prices stay the same. The price is close to the amount that has to be paid for the system, so major savings are not expected. Losses, anyway, should not be suffered. When doing the tender for a bigger batch, some discounts are expected, and the possible subsidies would lower the total costs. In the case of Ruusutarha, the systems could easily pay themselves back and start making profit. Anyhow, usage of solar energy hardly is done only for seeking the savings but also because of its green values.

The existence of solar power raises the value of the cottages, and Teijo-Talot could easily ask for 3500-5000 € more for them. In that way Teijo-Talot would get the profit at once, and the customer would get it over time in the form of savings in electricity costs.

8 CONCLUSION

The usage of solar power is a modern choice. Its profitability can be difficult to estimate, but due to the long lifetime, even a smaller system can pay itself back, and make profit, too. In the future, when the battery technology develops, exploitation gets more viable, and even the separation from the regular power grid becomes possible.

Design work for a case like Ruusutarha is complicated. The community as a whole forms a bigger entity, but the individual cottages themselves are rather small. Consumption in one cottage can be so low that the solar power systems are better to be designed relatively small. The alternative equipment is fewer when implementing a smaller power system, but with micro-inverters a working installation can be created, and if necessary, the system can be easily increased.

Undeveloped battery technology limits the possibilities of efficient power production, but working within the community broadens the opportunities, and the system can be exploited better.

Working as a community enables taking the full advantage of the solar power systems. Communality requires additional arrangements, but in Ruusutarha the process can be easily managed at the same time with the sales of the properties.

Connecting the solar power systems to the regular power grid demands some work, and the final size of the whole system in Ruusutarha has an impact on the permit work. Nevertheless, micro production has become more and more common, and at the same time, the practices have become easier to manage.

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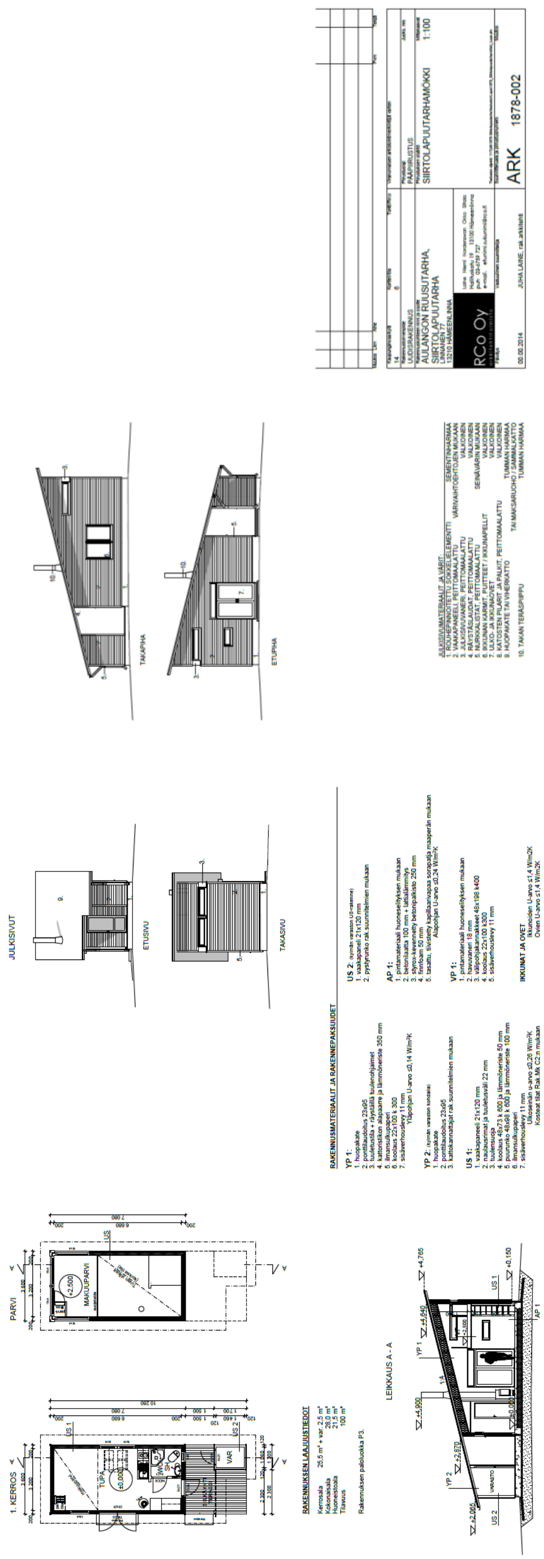
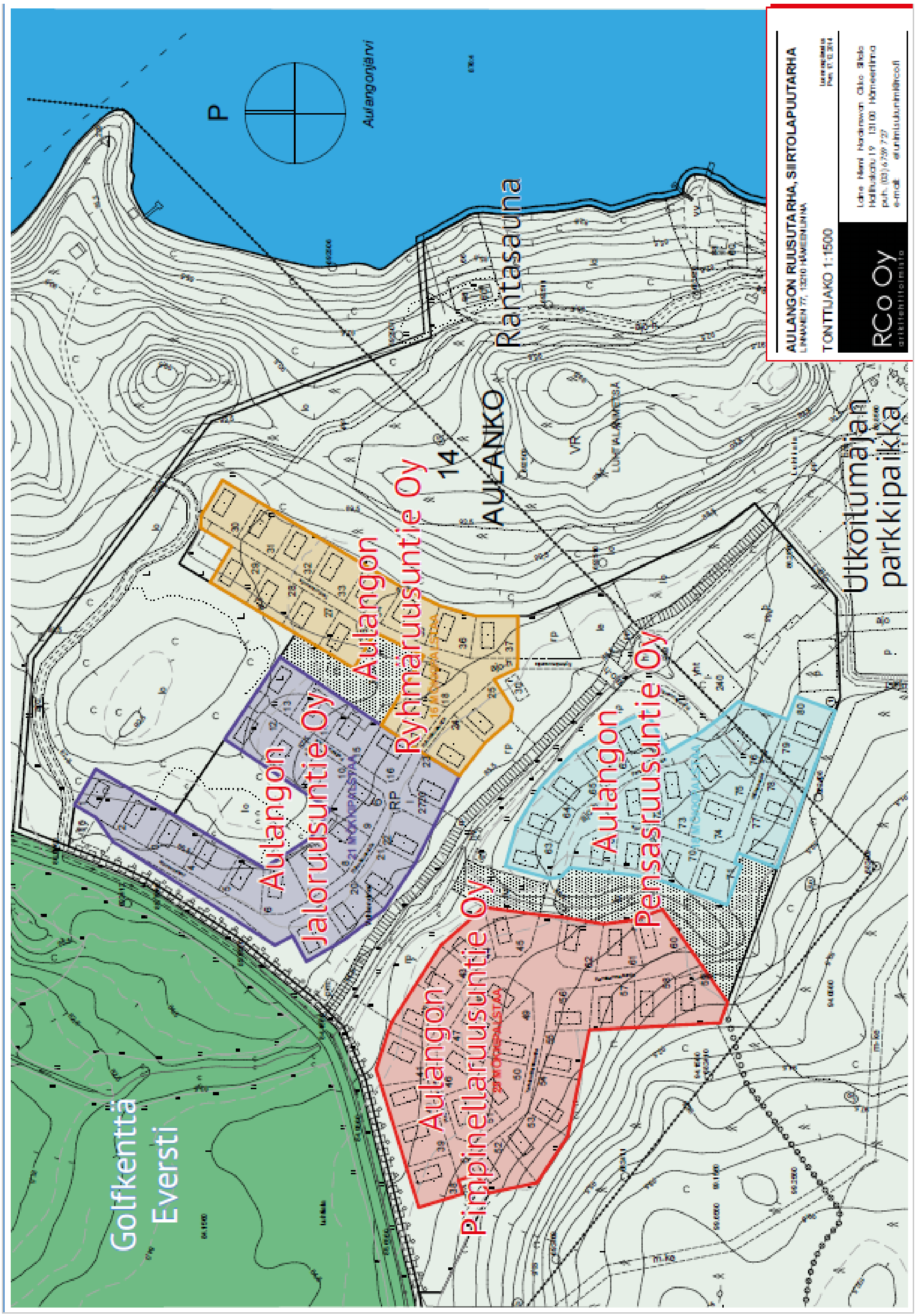
Appendix 1

MAIN DRAWING OF RUUSUTARHA COTTAGE



Appendix 2

Plot division in Ruusutarha

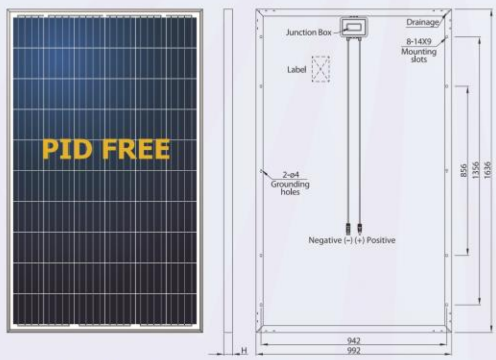


Appendix 3

4BB SS250P-SS265P POLY CRYSTALLINE SILICON MODULE

SaloSolar

4BB SS250P-SS265P
Poly-Crystallinen Silicon Module



MECHANICAL DATA

Length (mm)	1636
Width (mm)	992
Depth (mm)	40
Weight (kg)	19.3
Cable Cross Section Size mm²	4
No. of Cells and Connections	60 (6*10)
No of Diodes	3

QUALIFICATION

Max. Systems Voltage	1000VDC/1500VDC
Temperature Cycling Range	-40°C~+85°C
Max Series Fuse	15 A
Max Win Load/Max Snow Load	2400Pa/5400Pa
Damp Heat Test	85°C and 85% relative humidity for 1000h
Hot Spot Free	100% EL inspection before and after lamination

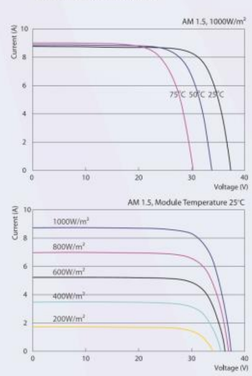
LINEAR WARRANTY
No more than 3% peak power degradation in **1 ST YEAR**
No more than 0,72% peak power degration in coming **24 YEARS**
Free from defects of materials and workmanship for **10 YEARS**

ELECTRICAL PARAMETERS

TYPE		SS-250W	SS-255W	SS-260W	SS-265W
	Rated Max Power at STC (W)	250,00	255,00	260,00	265,00
STC	Max Power Voltage/Vmp (V)	29,98	30,25	30,51	30,71
AM 1.5,	Max Power Current/Imp (A)	9,34	8,43	8,52	8,63
1000W/m²,	Open Circuit Voltage/Voc (V)	37,41	37,54	37,65	37,81
Module terperature	Short Circuit Current/Isc (A)	8,79	8,94	9,09	9,24
25°C	Modele Efficiency (%)	15,40	15,71	16,02	16,33
NOCT	Rated Max Power at NOCT (W)	180,40	184,1	187,5	191,00
AM 1.5,	Max Power Voltage/Vmp (V)	29,70	27,8	27,90	28,00
800W/m²,	Max Power Current/Imp (A)	6,51	6,62	6,72	6,82
Ambient	Open Circuit Voltage/Voc (V)	34,10	34,2	34,30	34,45
Temperature	Short Circuit Current/Isc (A)	7,11	7,23	7,35	7,47
20°C, Wind	Modele Efficiency (%)	13,89	14,18	14,44	14,71
Speed 1m/s					

Temperature Coefficient of Pm	-0.44%/°C
Temperature Coefficient of Voc	-0.32%/ °C
Temperature Coefficient of Isc	+0.055%/ °C
Nominal Operating Cell Temperature	45 °C ±3 °C
Output Tolerance	0~5W

250W CURVES



MODULE SIZE	CONTAINER	20'GP	40'HC
	Pieces Per Pallet	25	25
1636*992*40	Pallets Per Container	6	28
	Places Per Container	150	700

Made in Finland
Specifications in this catalog sheet are subject to technical changes and product innovations. SaloSolar reserves the right of final interpretation.

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Appendix 4

Electrical plan of Ruusutarha cottage