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APPLICATION OF SOLAR ENERGY IN HARJAKANGAS ARTIFICIAL GROUNDWATER PLANT

Degree Programme in Environmental Engineering

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The purpose of this thesis was to research different options for the application of solar energy in a raw water purification plant in Harjakangas. The research will include both photovoltaic and solar thermal systems of different sizes, their prices, payback times and estimated productions. The studied photovoltaic system options were the sizes of 5, 10 and 20kW. The studied solar thermal systems included either 2, 3 or 4 collectors and the different options for the 4 collector system were studied separately. The thesis will first go through background information of the plant itself and continues to examine the collected data of electricity and heating oil consumption. After this is the solar thermal system simulation, options and payback times followed by the estimated production and payback times of the photovoltaic systems. An installation plan for the selected system written in Finnish will also be included as an appendix.

TABLE OF CONTENTS

1 INTRODUCTION

The water used by the city of Pori comes from a raw water purification plant in Harjakangas which was established in 1976 and renovated in 2000-2001. The water purification consists of two phases, mechanical and chemical, the latter also includes the formation of artificial groundwater.

Operating a plant capable of delivering fresh water to over 85 thousand inhabitants in the city takes tremendous amounts of energy, mostly electricity, but heating of the plant itself also consumes a considerable amount of light heating oil. With the ever-rising costs of fossil fuels and a drive towards more sustainable operation in mind, Porin Vesi has approached the author with a task to research the possible application of solar energy in the plant.

This thesis will go through the consumption of the plant, different options for both photovoltaic and solar thermal systems and the gained savings/payback times of these systems, focus being on a solar thermal system. These system options will be presented to the client and the appendix will include an installation manual for the selected system in Finnish.

2 BACKGROUND AND ENERGY CONSUMPTION

2.1 Background

The operation of the plant is based on mechanical and chemical precipitation as well as the formation of the artificial groundwater.

In the first phase the water is led to the plant through a 3mm screen after which the water is pumped to the chemical precipitation which removes the humus causing the brown tone of the raw water. The chemicals used in this process are poly aluminum chloride and chalk. The precipitated humus is then removed in flotation where a stream of air and water pushes it to the surface. The water is then led through two lines consisting of 28 sand filters in total, this removes most of the smaller particles remaining in the water.

In the second phase the filtrated water is led to the formation of artificial ground water, which takes place under the nearby eskers. The formation is done through several absorption pools. The water stays underground from two to three weeks after which it is pumped back to the plant for disinfection and pH-adjustment. The chemicals used in this are sodium hypochlorite and chalk. (website for the city of Pori, 2016)

The whole process includes several high-powered pumps and other technical equipment which are the main reasons for the high electricity consumption of the plant. In the following chapter this will be gone through in more detail.

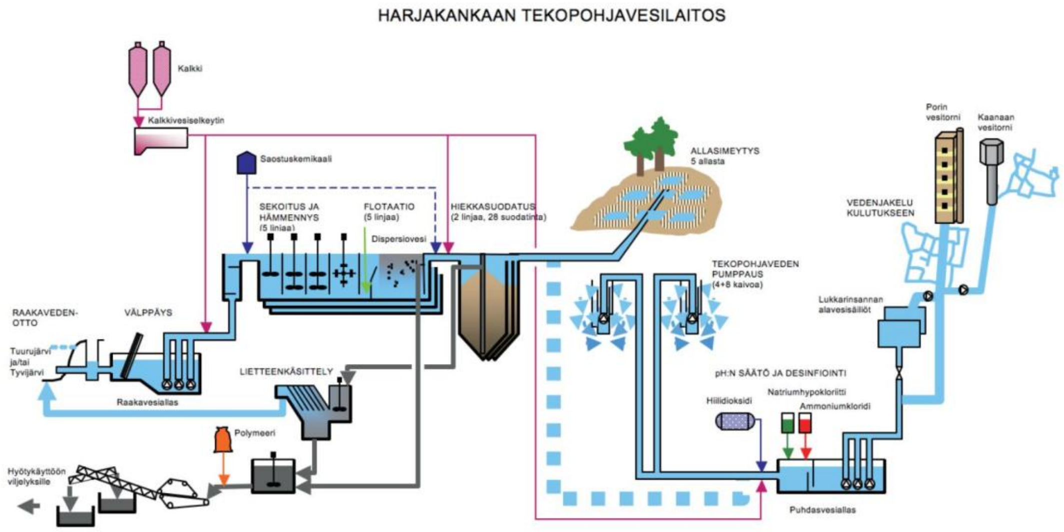


Figure 1 Harjakangas artificial groundwater plant process (Porin Vesi 2000)

Figure 2 The two oil boilers in the technical room (Author, 2016)

The existing heating system of the plant consists of two 75kW oil boilers seen in figure 1 which provide the hot water to the office as well as to some of the processes.

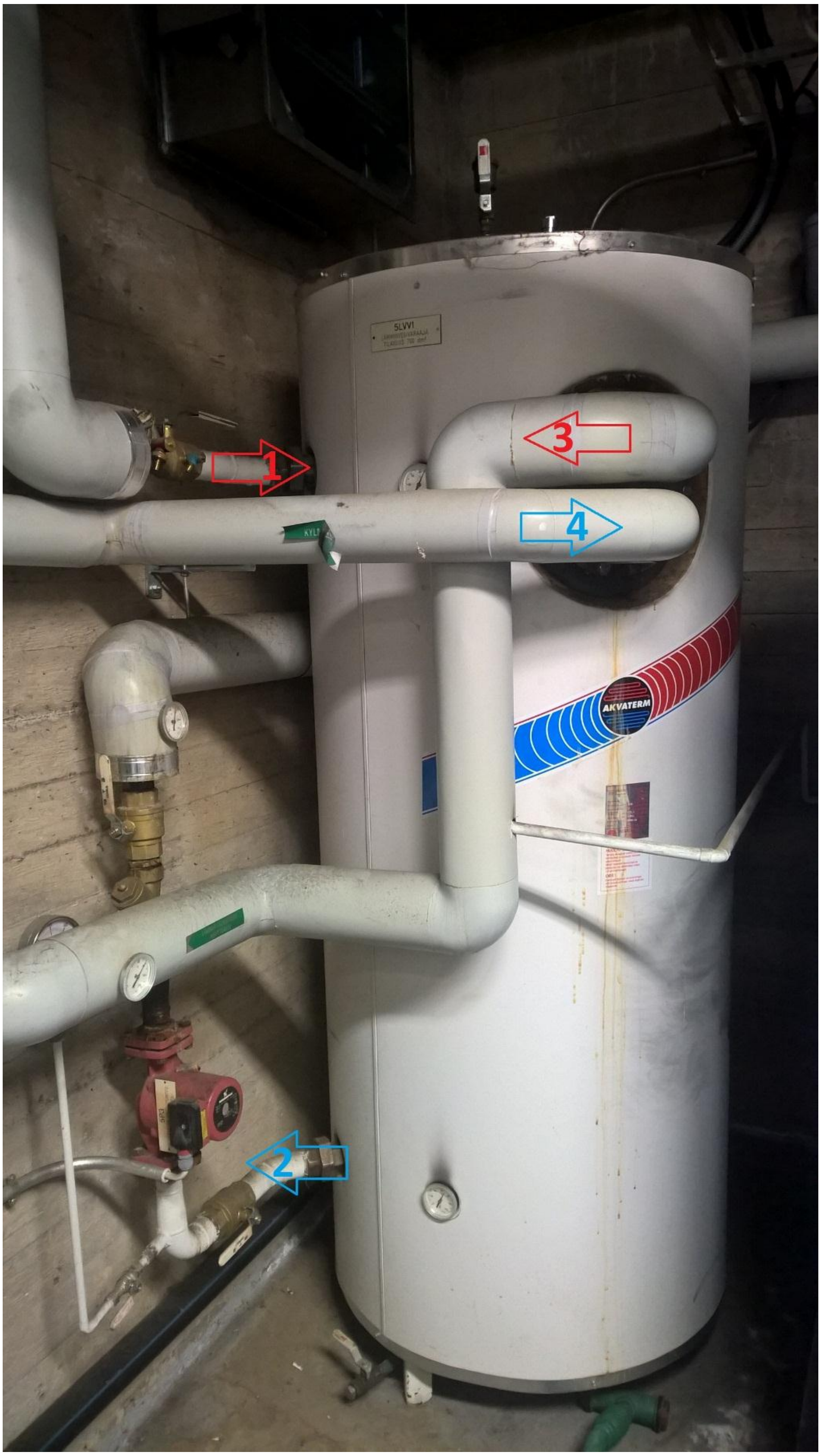


Figure 3 Hot water reservoir. Connections 1 and 2 to the boilers, connections 3 and 4 to the circulation (Author, 2016)

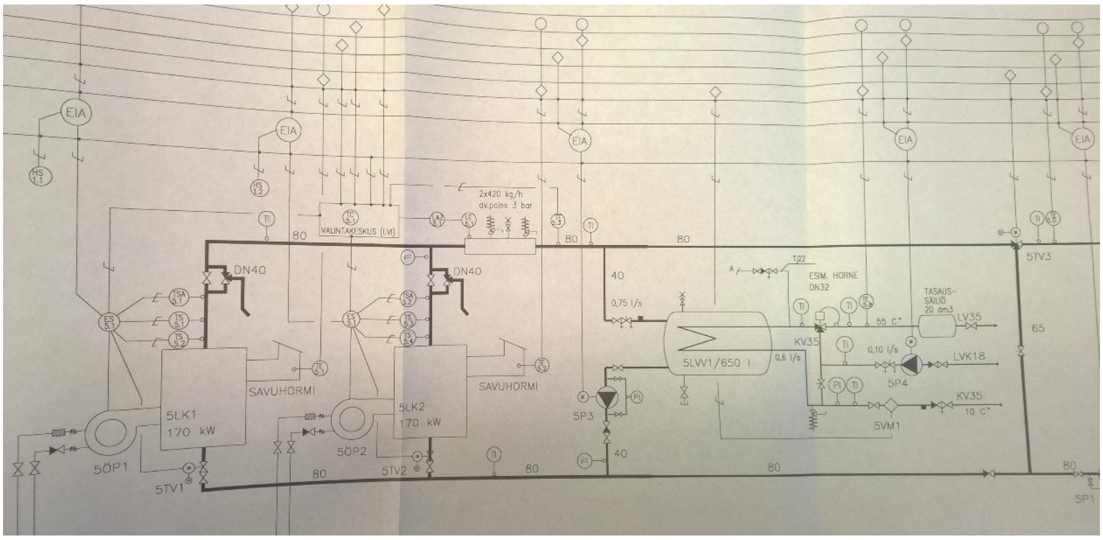


Figure 4 Technical drawing of the heating system (Author, 2016)

The existing hot water reservoir does not have an input for a solar heating coil and is therefore likely to get replaced in the new configuration for heating.

Figure 5 The planned location for the solar collectors (Author, 2016)

The spot on the roof planned for the solar collectors was chosen due to its close proximity to the existing heating system, the pipes seen on the right side of figure 5 come from the two boilers downstairs.

Figure 6 Picture from the roof towards the south (Author, 2016)

There are some trees possibly shading the area for the photovoltaic cells in figure 4, but they can be cut down.

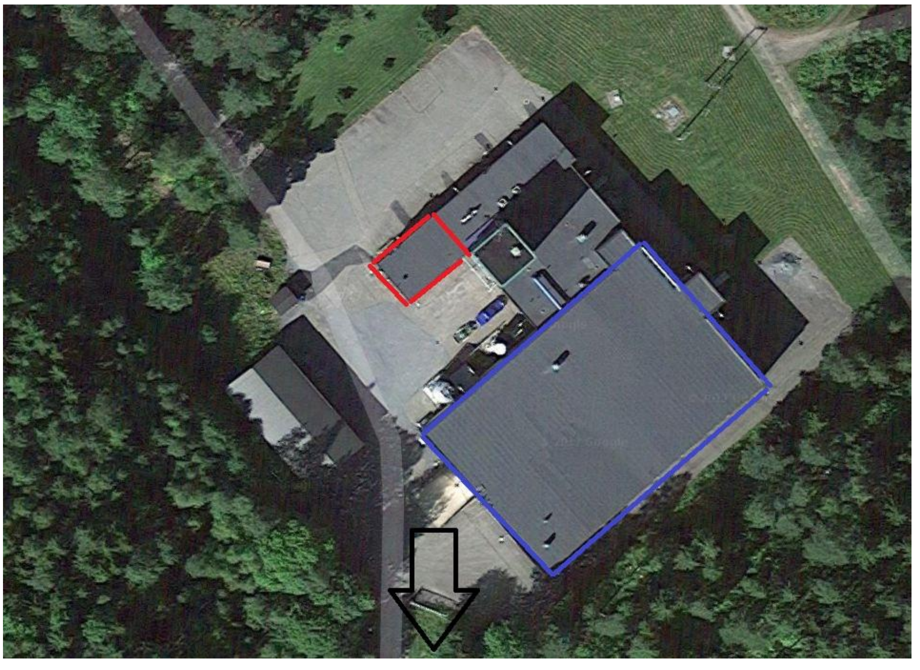


Figure 7 Aerial view of the facilities (Google maps)

The red square in figure 7 is the area planned for solar thermal system, whereas the blue square is for the photovoltaic. The arrow in figure 7 is pointing to south.

2.2 Energy Consumption

As mentioned before, plants such as this consume massive amounts of energy, around 3053MWh of electricity and 617MWh worth in heating oil annually. Therefore it is only logical from both ecological and economical viewpoint to try to cover some of it with renewables.

2.2.1 Electricity consumption

The data for electricity consumption has been collected over the span of four and a half years, starting from 2012. The biggest consumers of electricity are the pumps and other equipment used for the creation of artificial groundwater, office lighting and -equipment contributing a smaller amount.

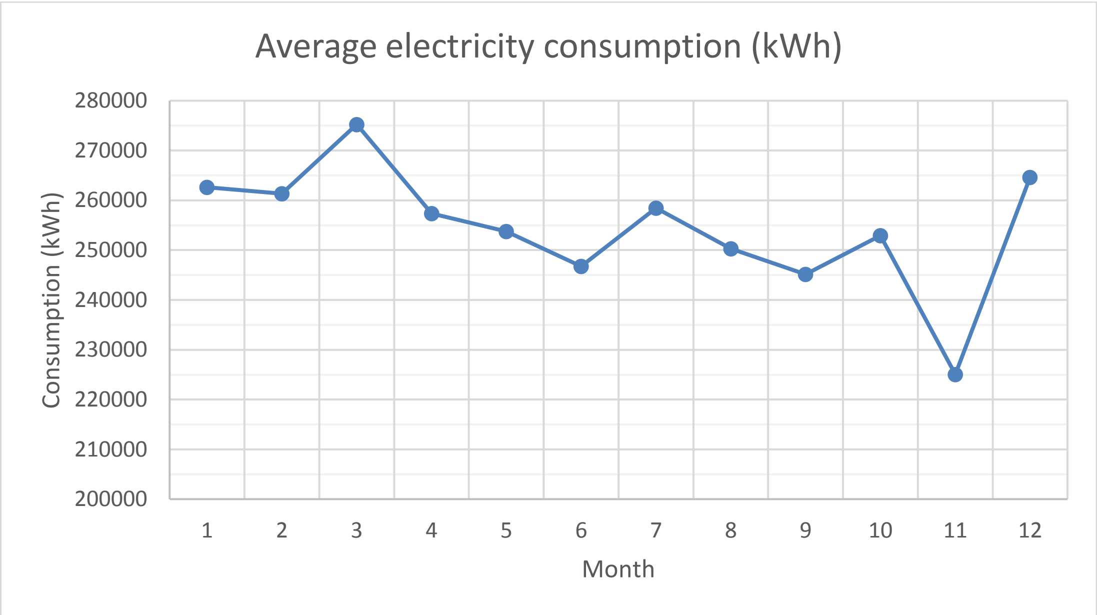


Figure 8 Average electricity consumption

It is important to notice that the data from 2016 has not been used in calculating the average in figure 8 since the data from that year was not complete. The major changes in the average consumption such as during November can be explained e.g. with maintenance.

2.2.2 Heating oil consumption

The heating oil consumption has also been collected during the span of four and a half years, in table 1 below, the average consumed liters have also been converted to kilowatt hours. One liter of oil amounting to ten kWh (Polttoaineiden lämpöarvot, hyötysuhteet ja hiilidioksidin ominaispäästökertoimet sekä energian hinnat 2010)

Table 1 Average heating oil consumption in liters and kWh

	Average oil consumption	
Month	Liters	kWh
January	10997.14	109971.4
February	9167.8	91678
March	7829.2	78292
April	4767.8	47678
May	2090	20900
June	1484	14840
July	2932.2	29322
August	905	9050
September	1922.5	19225
October	4997.5	49975
November	5773	57730
December	8872.75	88727.5

3 RESEARCH OF THE SOLAR SYSTEMS

3.1 Solar Thermal

When it comes to solar thermal systems, there are several different options available. These include evacuated tubes, systems with parabolic mirrors, Fresnel technologies and so forth. For the sake of simplicity and economic viability a system with flat plate solar collectors was chosen.

To put it into a layman's terms, the sun's radiation heats up the heat transfer fluid in the collectors, which is then led to the coil in the hot water reservoir to release the said heat to the water. All of this is monitored and controlled via the control unit which receives data from the temperature sensors in the collectors and the water reservoir and the flowmeter. The heat transfer fluid used in this application is a mixture of propylene glycol and water for its anti-freezing properties.

To compare the systems of different sizes, a simulation program called GetSolar professional was used to acquire data. The simulation was done with systems of 2,3 and 4 collectors, all the systems had the same 700-liter hot water reservoir. Different options of a solar thermal system with four collectors are also used to compare from an economic viewpoint. The collectors in the simulation were in the optimal 45°-degree angle and positioned straight towards south with no shading.

3.1.1 GetSolar energy/eco balance simulation

Table 2 Energy balance simulation with 4 collectors

Month	**Production (sun)** [kWh]	**Radiation (sun)** [kWh]	**Alternative heating** [kWh]	**Hot water coverage** [%]	**Efficiency** [%]
January:	**20**	88	505	4	23
February:	**69**	245	423	14	28
March:	**314**	893	230	59	35
April:	**475**	1332	65	89	36
May:	**499**	1414	62	90	35
June:	**493**	1417	49	90	35
July:	**520**	1382	54	93	38
August:	**394**	946	142	73	42
September:	**333**	806	191	64	41
October:	**150**	378	374	29	40
November:	**12**	53	492	2	23
December:	**11**	44	499	2	25
total:	**3290**	8999	3086	52	37

Annual yield of the collectors: 411 kWh/m²

Table 3 Eco balance simulation with 4 collectors

Month	**Production (sun) [kWh]**	**Energy savings [kWh]**	**[litres]**	**CO2-savings [kg]**
January:	20	15	**1**	5
February:	69	80	**8**	25
March:	314	410	**41**	126
April:	475	1006	**100**	309
May:	499	1138	**113**	350
June:	493	1177	**117**	362
July:	520	1145	**114**	352
August:	394	682	**68**	210
September:	333	584	**58**	180
October:	150	180	**18**	55
November:	12	8	**1**	3
December:	11	4	**0**	1
total:	3290	6429	**638**	1977

Relative energy saving: 35.4%

In table 2 we can see the production of the collectors in kWh, the radiation from the sun, alternative heating energy needed, hot water coverage and respective system efficiency percentage.

It is important to note that the alternative source of heat will still be the two existing oil boilers and that the hot water coverage is only calculated for office needs, 300 liters of hot water per day. In table 3 eco balance simulation the important figures to notice are the energy savings and the amount saved in carbon dioxide emissions.

Shading has not been accounted for in these simulations since it should not cause an issue. The towering structure in the nearby roof is the only concern in this case, but the shading simulation done in Sketchup shows that it should not cause shading, and even if it did, it would only be on an early morning during the winter when the production is already expected to be low. It is also important to note that shading is not as big of an issue with solar thermal systems as it is with photovoltaic where the shading of a single cell can bring down the production of the whole row of panels connected together. Using several inverters and maximum power point tracking can help to counter this but the issue remains.

3.1.2 GetSolar hot water coverage and system efficiency

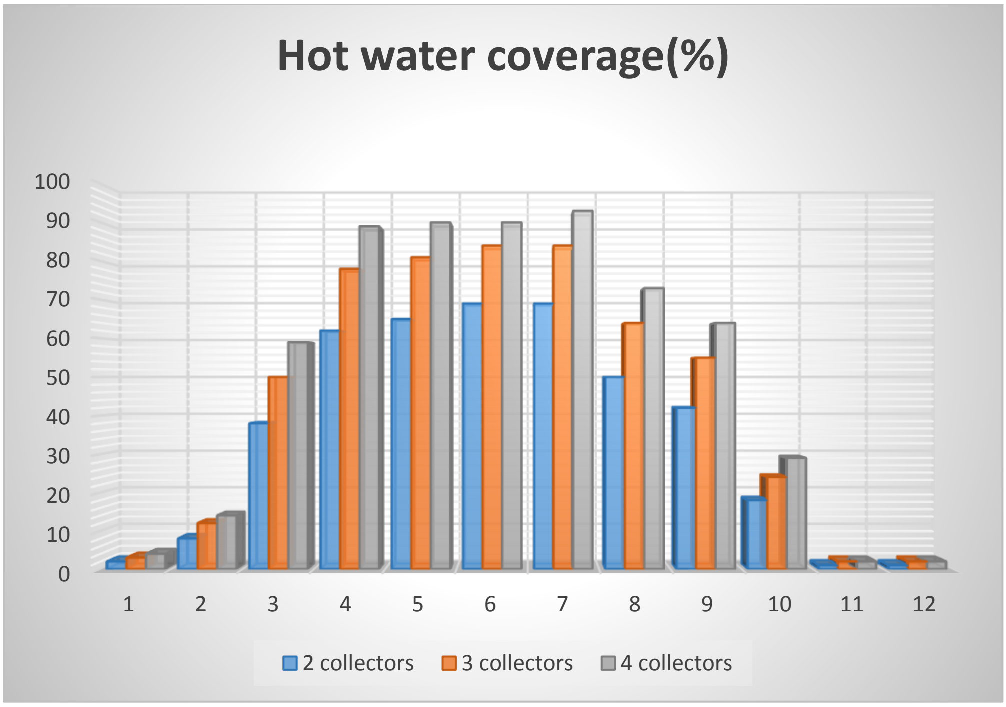


Figure 9 Hot water coverage from simulations

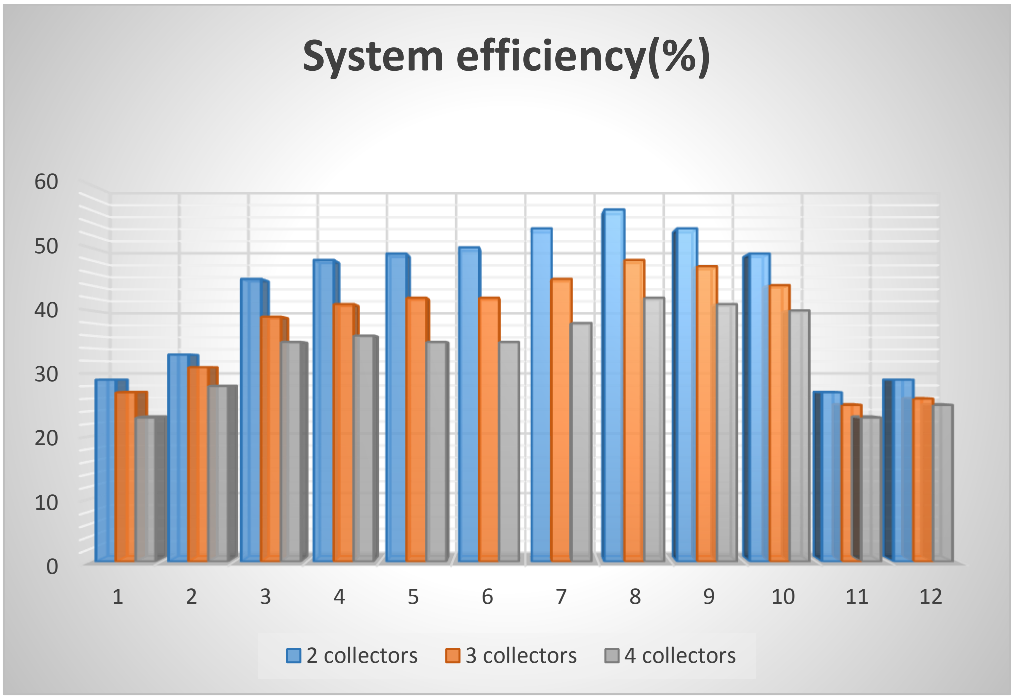


Figure 10 System efficiency from simulations

It is important to note in figures 9 and 10 that while system efficiency goes down when the amount of collectors increases, even a four collector system is still at an adequate efficiency level and provides much greater hot water coverage than a system of smaller size. Thus it is recommendable to invest in a four collector system from the efficiency and hot water coverage viewpoint.

The plant could probably use an even bigger system and minimize the usage of the oil boilers or take one of them out altogether to make room for a bigger hot water reservoir which would be needed for a bigger solar thermal system, but it is unlikely only one boiler could provide hot water during winter while the production of the system is down.

In the future it is possible to look into other sources of heat during winter, such as geothermal or pellet boiler, which could easily be integrated into the already existing system.

3.1.3 Solar thermal system options and payback times

In solar thermal system options, the systems were all the same size, which is 4 collectors covering around 10 square meter area. In addition, all the systems need either a separate heat exchanger or a new hot water reservoir (website of energiakauppa, 2017). The example heat exchanger is type B3-23-30 with 0.69 square meter surface area and 7.2kW power output in a solar thermal application. The example hot water reservoir is Akva Solar 750 with 3 coils, one of which for solar thermal.

To calculate the payback time in figure 12, a price of 0.92 euros per liter was used (website of consumer direct, 2017).

In figure 10 we can see the essentials of the system, where both the collectors and the oil boilers provide heat for the hot water reservoir. However, this figure does not show the option with the heat exchanger, but in that configuration the heat from the collectors would be directed to the hot water line going from the boilers to the hot water reservoir applying the heat exchanger mentioned earlier.

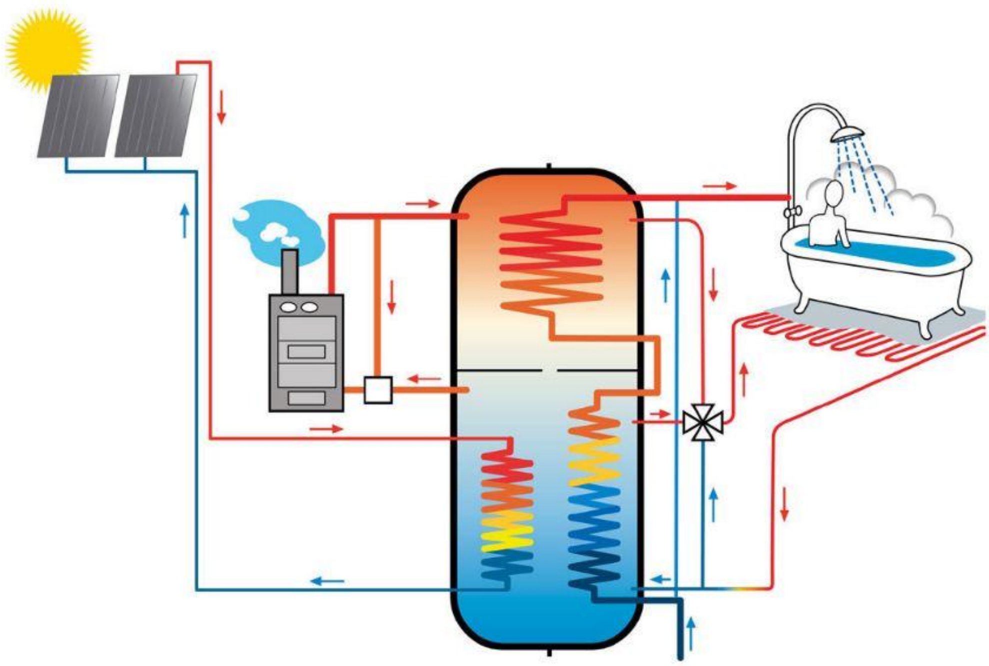
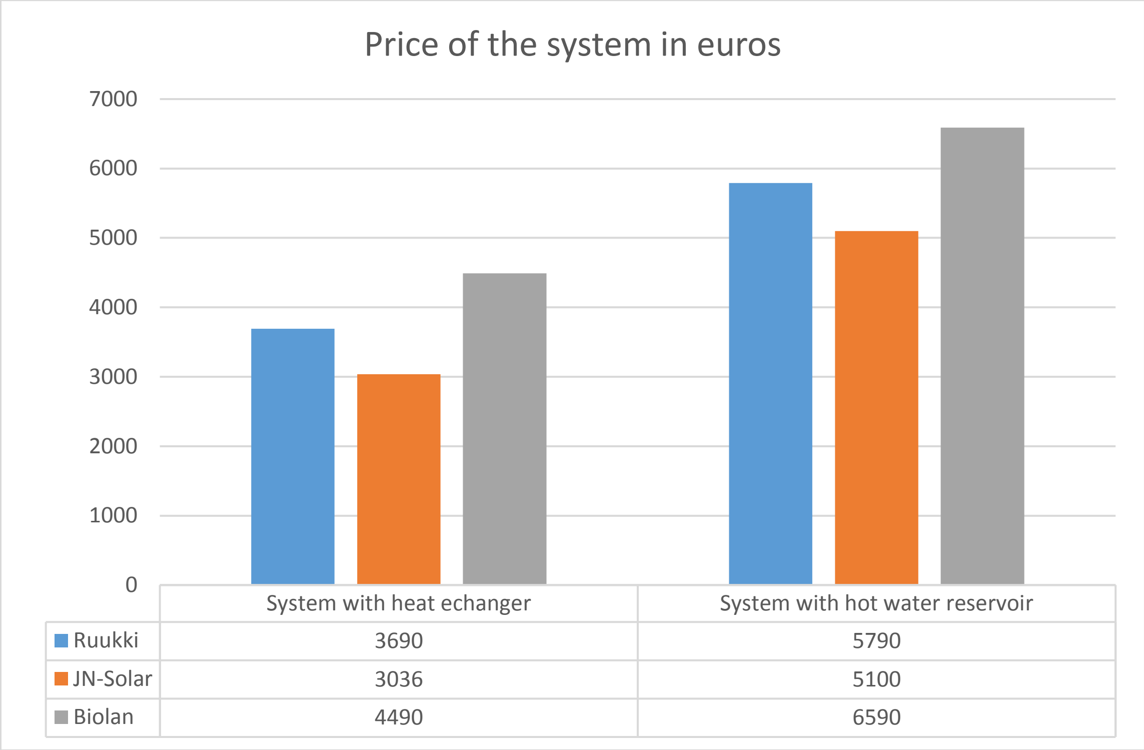


Figure 11 The solar thermal system simplified (Ympäristöenergia oy)



	System with heat echanger	System with hot water reservoir
Ruukki	3690	5790
JN-Solar	3036	5100
Biolan	4490	6590

Figure 12 Price of the different systems

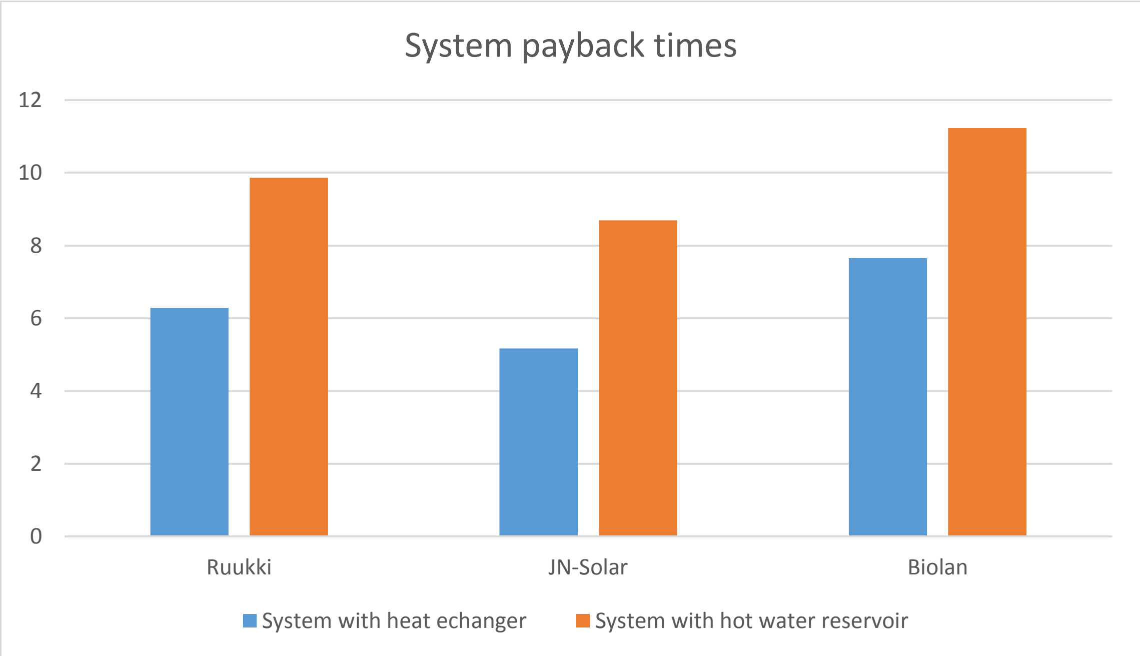


Figure 13 System payback times

From figures 12 and 13 it is important to note that while the system price and payback times are much higher for a system with a new hot water reservoir, it would significantly increase the efficiency. If the solar thermal system were to be integrated directly into the existing system with a heat exchanger it would somewhat defeat the purpose of the system.

The main point in which being that a solar thermal system is the most efficient when the water in the bottom of the hot water reservoir is preheated with the heat from the collectors and only after that the thermostat would recon if it is necessary to apply secondary heating from the oil boilers.

If a heat exchanger were to be used, the heat from the solar collectors would just be mixed in with the already hot water from the boilers for no greater advantage, which would greatly decrease the efficiency of the system. Thus, it is highly recommendable to invest in a new hot water reservoir that would have the solar heating coil already installed.

3.2 Photovoltaic

While it is important to note that the focus was mainly on solar thermal systems, options viable for photovoltaic were also considered. Offer for these 5kW, 10kW and 20kW systems was provided by a local solar energy system resale company, Satmatic. The price of the electricity was set to 8 c/kWh (website of Pori Energia, 2017).

The panels used are polycrystalline, and while they tend to have slightly lower efficiency and heat resistance due to the lower purity of silicone used than monocrystalline panels, they are much cheaper and the process used to make them wastes less silicone (Maehlum M.A, 2015)

The inverters used are three-phase Symo models manufactured by Fronius with two maximum power point trackers for the highest efficiency.

3.2.1 System options

The offer can be seen in appendix 1, these prices were used to calculate the payback time of each system. The system prices were 5160, 9560 and 15500 euros. The details of the solar panels and the inverters of the systems can be seen in appendix 2, although the panels might be manufactured by Ankara solar, the technical and dimensional features of the individual panels are identical.

The maximum amount of panels the roof could fit is defined to be 80, which equals to 20kW peak power. It might be possible to fit even more panels on the roof if the angle is set to be smaller without sacrificing too much from the production, for example with 25 °-degree angle the system would still produce around 96% of the production of a system with a more optimal angle. Of course, a steeper angle would mean slightly better production during late autumn and early spring while cutting back on the overall yearly production.

With this in mind, the panels in the photovoltaic production estimation tool were set in the optimal 45°-degree angle facing straight to the south with no shading. It is important to note that the production might be lower in case the trees causing shading in front of the plant are not cut down.

3.2.2 System production and payback times

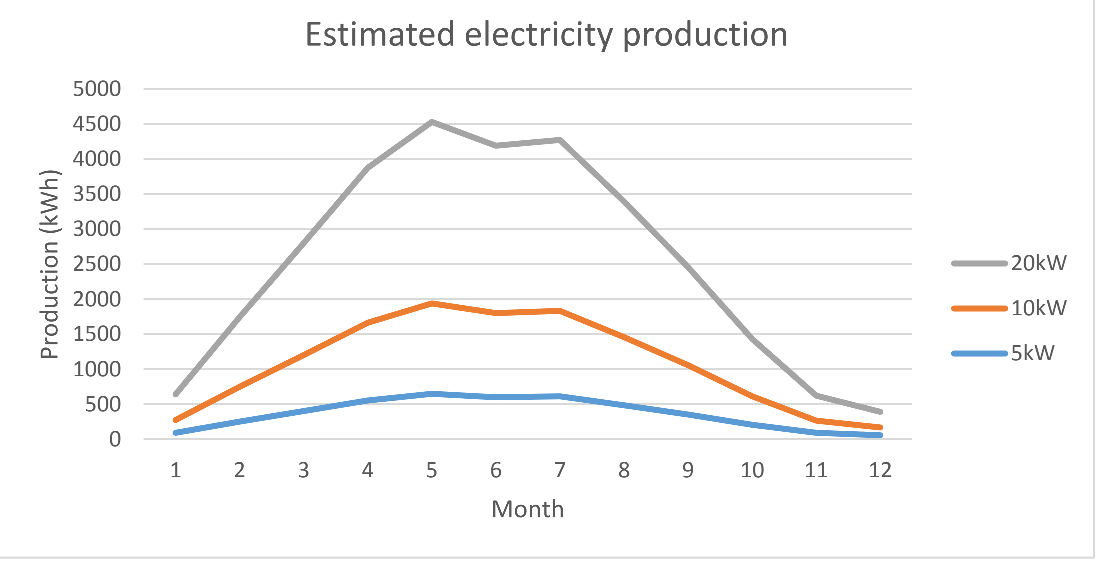


Figure 14 Estimated production (PVGIS estimation tool)

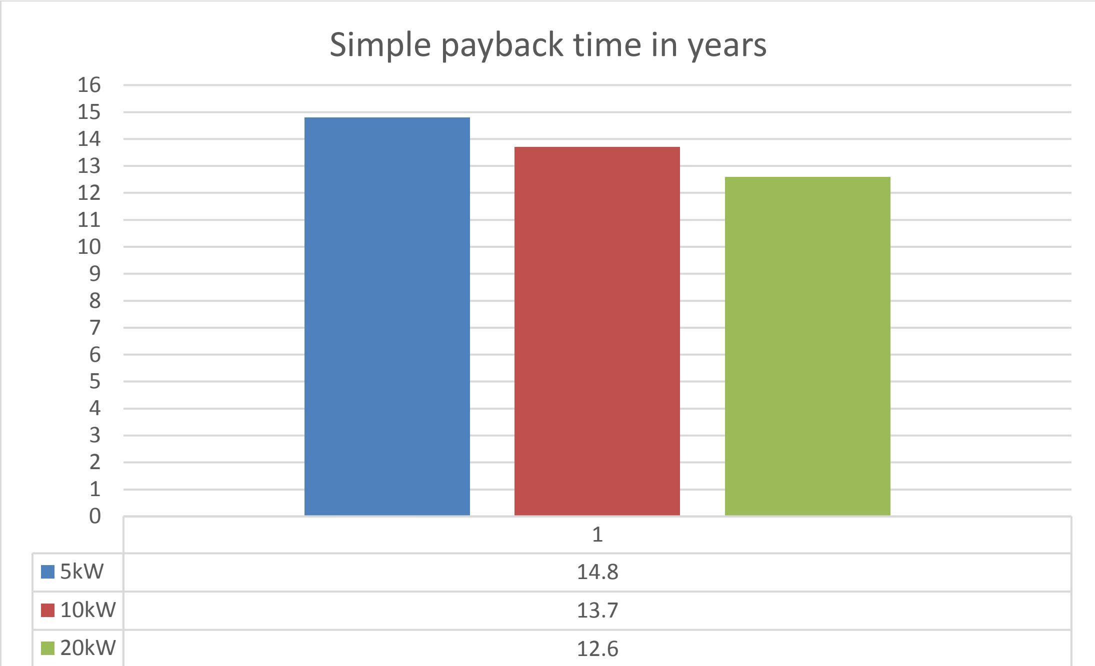


Figure 15 System payback times

In figure 14, where we can see the estimated production of the systems, the decline in production during the summer months can be explained by the heat affecting the efficiency of the system.

Figure 15 above shows the relative payback times of the systems calculated with the simple method, where the cost of the system is simply divided by the cost of the energy replaced by the produced electricity.

The assumptions in this method are that the maintenance costs remain minimal and that all the energy produced by the system is consumed by the plant itself. It is safe to say that at least the latter remains true no matter the conditions.

To calculate the payback time more precisely, a profitability tool created by Aalto-university for Finsolar project was used. The starting values used for the calculation can be seen in appendix 5.

This tool takes into account the rise of the cost of bought energy (1%/a), the cost of changing the inverter after 15 years, the economical support for the investment (20%) referenced from the website of karhuseutu and the decline in electricity production during the lifetime of 30 years (0.5%/a).

This was done only to the 20kW system, since it is the most economically viable and to get the support for the investment, the minimun cost needs to be over 10 000 euros. The final results received from the calculation tool can be seen in table 4 below.

Table 4 Conclusions

Conclusions: Production and viability of the system

Networth of the investment, the total production during 30 years of use	**13,634 €**	**euros**
Payback time	**12**	**years**

All things considered, this tool assumes similar, even slightly lower, payback time for the 20kW system as the simple payback time calculation method. Twelve years is still very reasonable, if not very good altogether. The payback time would be even lower for a private customer, but a plant this size gets a better deal for the price of electricity and that builds the payback time higher.

3.2.3 Price per watt

To further investigate the economical viabilities of the systems, a simple calculation of euros per peak power in watts was made, in this calculation the initial investment in the system is divided by the peak power of the system. This calculation is to show what is the amount of initial investment needed in euros to gain one watt of power. The smaller the initial investment, the better.

And as we can expectedly see from table 5 below, it is the most economically viable to invest in a 20 kW system.

Table 5 Euros/Watt calculation results

System	€/W
5kW	1.032
10kW	0.956
20kW	0.875

4 CONCLUSIONS

It is easy to argue that both solar thermal and photovoltaic systems are very viable options for Harjakangas artificial groundwater plant offering a stable source of renewable energy with reasonable payback times. However, with the initial investment of solar thermal system being so much lower compared to a photovoltaic system and with a smaller payback time, even with a new hot water reservoir, a solar thermal system would be preferred in this application. Also, to support this argument it is important to note that the solar thermal system covers 55% of the hot water need in office use and with 37% efficiency, whereas even the 20kW photovoltaic systems estimated production covers only roughly 0.6 % of the average electricity consumption.

The optimal size of the solar thermal system was determined from the simulations to be 4 collectors, since it has the biggest hot water coverage with still reasonable efficiency. A smaller system would be more efficient, but it would have a smaller coverage whereas a bigger system would have better coverage but worse efficiency. It is also highly recommendable to invest in a new hot water reservoir to gain the maximum efficiency of the solar thermal system.

REFERENCES

-Amerisolar, cited 12.12.2016

http://www.weamerisolar.com/product1_show.php?id=147

-Biolan ekoasuminen, cited 12.12.2016

http://www.ekoasuminen.fi/

-Consumer direct, cdfin.info

http://www.cdfin.info/light.html

-Energiakauppa.com, Ympäristöenergia oy, cited 5.2.2017

http://www.energiakauppa.com/epages/energiakauppa.sf/fi_FI/?ObjectPath=/Shops/2014082005/Products/21010

-Energy.gov, cited 20.2.2017

https://energy.gov/energysaver/heat-transfer-fluids-solar-water-heating-systems

-Fronius international, cited 12.12.2016

http://www.fronius.com/cps/rde/xchg/fronius_international/hs.xsl/83_28694_ENG_HTML.htm#.WKCf_m996Uk

-GetSolar professional

-Gioioso Matteo ja Katajisto Ville, asennusohjeet Solarleap-projektiin 2015.

-Hewalex installation manuals for flat plate solar collectors and pump and control unit. Cited 22.2.2017 http://www.hewalex.eu/en/download/technical-documentation/

-JN-Solar.fi, cited 12.12.2016

http://www.jn-solar.fi/fi/

-Juntunen Jouni, Jalas Mikko ja Auvinen Karoliina. Kannattavuuslaskuri Finsolar-projektille. 19.11.2015

http://www.finsolar.net/aurinkoenergian-hankintaohjeita/kannattavuuslaskurit/

-Karhuseutu.fi, investointituki yrityksille. Cited 22.2.2017

http://www.karhuseutu.fi/leader_karhuseutu/yrityksille/investointituki

-Maa ja Vesi oy, Porin Vesi 2000.

-Maehlum M.A, 2015. Article on the website of energy informative. Cited 20.4.2017

http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/

-Polttoaineiden lämpöarvot, hyötysuhteet ja hiilidioksidin ominaispäästökertoimet

sekä energian hinnat 19.4.2010 Motiva Oy. Cited 1.1.2017.

http://www.motiva.fi/files/3193/Polttoaineiden_lampoarvot_hyotysuhteet_ja_hiilidioksidin_ominaispaastokertoimet_seka_energianhinnat_19042010.pdf

-Porin Energia, sähkön myyntihinnat. Cited 1.1.2017

https://www.porienergia.fi/Hinnat/#.WKDTH2996Uk

-Porin kaupunki, website. Cited 12.12.2016

https://www.pori.fi/porinvesi/palvelut/talousvedenvalmistus.html

-Photovoltaic Geographical information system, cited 12.12.2016

http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?lang=en&map=europe

-Resol ammattiasentajan käsikirja, 2016. Cited 22.2.2017

http://www.resol.de/Produktdokumente/11205271_FlowSol_B.monfi.pdf

-Ruukki aurinkoenergiaratkaisut, Rautaruukki oyj cited 5.2.2017

http://www.energiakauppa.com/WebRoot/vilkasfi01/Shops/2014082005/MediaGallery/pdf/Ruukki/FI_RuukkiAurinkoenergiaratkaisut_Hinnasto27102014.pdf

APPENDIX 1

SYSTEM OFFERS

Satmatic Oy

Hannu Poussu

Liittyy tarjoukseen: **SAMK insinöörityötä varten** 12.12.2016

POSITIOKOHTAINEN HINTA-ERITTELY

	POSITIO	KPL	à-HINTA	YHTEENSÄ	HUOM!
1	Aurinkosähköjärjestelmä 5kW	1	5 160 €	5 160 €	
2	Aurinkosähköjärjestelmä 10kW	1	9 560 €	9 560 €	
3	Aurinkosähköjärjestelmä 20kW	1	17 500 €	17 500 €	

Toimituksen kokonaishinta 32 220 €

JÄRJESTELMÄN LAITTEISTO POS1:

- Invertteri Fronius Symo 5.0-3-M, sis LAN/WLAN ja webserver — 1 kpl
- Turvakytkin verkosta erottamiseen — 1 kpl
- Paneeli AnkaraSolar tai AmeriSolar 260W — 20 kpl (5,2kWp)
  Paneelin mitat (P x L x S) 1640 x 992 x 40mm
- Paneeliketjun + ja – -liittimet — 4+4 kpl
- Paneelikaapeli (DC) 4mm² punainen ja musta — 30+30 m
- Varoituskilvet turvakytkimelle ja sähkökeskukseen
- Merialumiiniset aurinkopaneelikiinnikkeet tasakatolle, Renusol, Schletter tai Satmatic

- Järjestelmän sähkösuunnittelu

POS2:
erot pos 1:een

- Invertteri Fronius Symo 10.0-3-M — 1 kpl
  -sisältää DC-ylijännitesuojan
- Paneelit — 40 kpl (10,4kWp)
- Paneeliketjun + ja – -liittimet — 8+8 kpl
- Paneelikaapeli (DC) 4mm² punainen ja musta — 150+150 m

POS3:
erot pos 1:een

- Invertteri Fronius Symo 20.0-3-M — 1 kpl
  -sisältää DC-ylijännitesuojan
- Paneelit — 78 kpl (20,28kWp)
- Paneeliketjun + ja – -liittimet — 20+20 kpl
- Paneelikaapeli (DC) 4mm² punainen ja musta — 350+350 m

TARJOUKSEEN EI SISÄLLY:

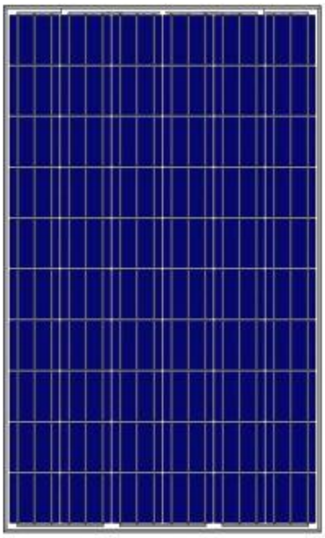
- Kiinteistön kattorakenteen lujuuslaskenta.
- AC-kaapelit ja mahdolliset AC-keskuksen vaatimat tarvikkeet
- Asennus ja asennustarvikkeet
- Mahdollisesti tarvittavat kestopuualustat
- Mahdolliset lisäpainot mikäli rakennetaan kelluva järjestelmä
- Mahdolliset maadoitustarvikkeet

Figure 16 Offer received from Satmatic

APPENDIX 2

SOLAR PANEL AND INVERTER DATASHEETS

AS-6P30



POLYCRYSTALLINE MODULE

ADVANCED PERFORMANCE & PROVEN ADVANTAGES

- High module conversion efficiency up to 16.90% through advanced manufacturing technology.
- Low degradation and excellent performance under high temperature and low light conditions.
- Robust aluminum frame ensures the modules to withstand wind loads up to 2400Pa and snow loads up to 5400Pa.
- Positive power tolerance of 0 ~ +3 %.
- High ammonia and salt mist resistance.
- Potential induced degradation (PID) resistance.

CERTIFICATIONS

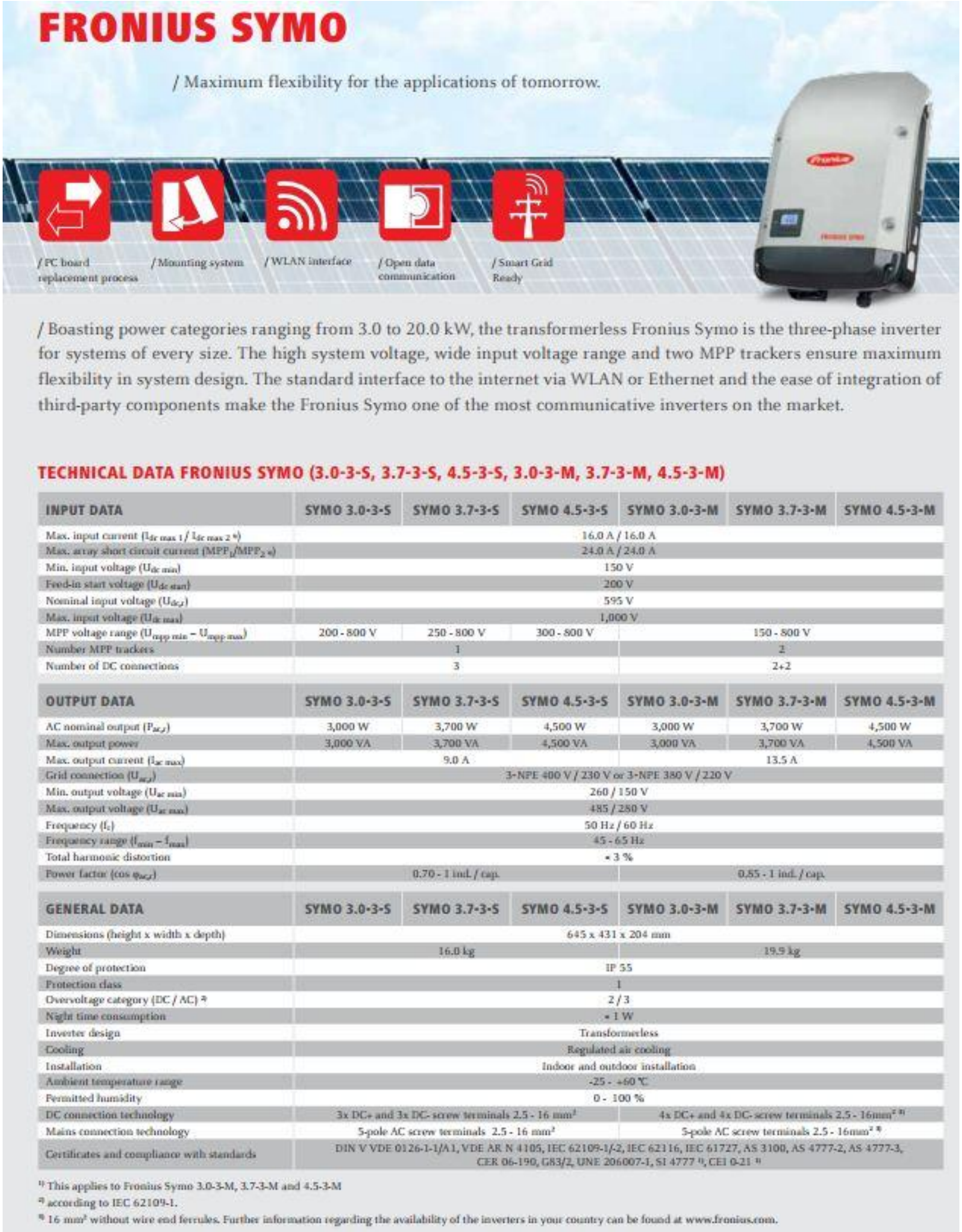
- IEC61215, IEC61730, IEC62716, IEC61701, UL1703, CE, ETL(USA), JET(Japan), J-PEC(Japan), MCS(UK), CEC(Australia), FSEC(FL-USA), CSI Eligible(CA-USA), Israel Electric(Israel), Kemco(South Korea), InMetro(Brazil), TSE(Turkey)
- ISO9001:2008: Quality management system
- ISO14001:2004: Environmental management system
- OHSAS18001:2007: Occupational health and safety management system

Passionately committed to delivering innovative energy solution

SPECIAL WARRANTY

- 12 years limited product warranty.
- Limited linear power warranty: 12 years 91.2% of the nominal power output, 30 years 80.6% of the nominal power output.

Figure 17 Amerisolar AS-6P30 solar panel data (Website of Amerisolar, 2016)



FRONIUS SYMO

/ Maximum flexibility for the applications of tomorrow.

/ PC board replacement process
/ Mounting system
/ WLAN interface
/ Open data communication
/ Smart Grid Ready

/ Boasting power categories ranging from 3.0 to 20.0 kW, the transformerless Fronius Symo is the three-phase inverter for systems of every size. The high system voltage, wide input voltage range and two MPP trackers ensure maximum flexibility in system design. The standard interface to the internet via WLAN or Ethernet and the ease of integration of third-party components make the Fronius Symo one of the most communicative inverters on the market.

TECHNICAL DATA FRONIUS SYMO (3.0-3-S, 3.7-3-S, 4.5-3-S, 3.0-3-M, 3.7-3-M, 4.5-3-M)

INPUT DATA	SYMO 3.0-3-S	SYMO 3.7-3-S	SYMO 4.5-3-S	SYMO 3.0-3-M	SYMO 3.7-3-M	SYMO 4.5-3-M
Max. input current ($I_{dc\,max\,1}$ / $I_{dc\,max\,2}$ [1)])	16.0 A / 16.0 A					
Max. array short circuit current (MPP_1/MPP_2 [1)])	24.0 A / 24.0 A					
Min. input voltage ($U_{dc\,min}$)	150 V					
Feed-in start voltage ($U_{dc\,start}$)	200 V					
Nominal input voltage ($U_{dc,r}$)	595 V					
Max. input voltage ($U_{dc\,max}$)	1,000 V					
MPP voltage range ($U_{mpp\,min}$ – $U_{mpp\,max}$)	200 - 800 V	250 - 800 V	300 - 800 V	150 - 800 V		
Number MPP trackers	1			2		
Number of DC connections	3			2+2		
OUTPUT DATA	**SYMO 3.0-3-S**	**SYMO 3.7-3-S**	**SYMO 4.5-3-S**	**SYMO 3.0-3-M**	**SYMO 3.7-3-M**	**SYMO 4.5-3-M**
AC nominal output ($P_{ac,r}$)	3,000 W	3,700 W	4,500 W	3,000 W	3,700 W	4,500 W
Max. output power	3,000 VA	3,700 VA	4,500 VA	3,000 VA	3,700 VA	4,500 VA
Max. output current ($I_{ac\,max}$)	9.0 A			13.5 A		
Grid connection ($U_{ac,r}$)	3-NPE 400 V / 230 V or 3-NPE 380 V / 220 V					
Min. output voltage ($U_{ac\,min}$)	260 / 150 V					
Max. output voltage ($U_{ac\,max}$)	485 / 280 V					
Frequency (f_r)	50 Hz / 60 Hz					
Frequency range (f_{min} – f_{max})	45 - 65 Hz					
Total harmonic distortion	< 3 %					
Power factor (cos $\varphi_{ac,r}$)	0.70 - 1 ind. / cap.			0.85 - 1 ind. / cap.		
GENERAL DATA	**SYMO 3.0-3-S**	**SYMO 3.7-3-S**	**SYMO 4.5-3-S**	**SYMO 3.0-3-M**	**SYMO 3.7-3-M**	**SYMO 4.5-3-M**
Dimensions (height x width x depth)	645 x 431 x 204 mm					
Weight	16.0 kg			19.9 kg		
Degree of protection	IP 55					
Protection class	1					
Overvoltage category (DC / AC) [2)]	2 / 3					
Night time consumption	< 1 W					
Inverter design	Transformerless					
Cooling	Regulated air cooling					
Installation	Indoor and outdoor installation					
Ambient temperature range	-25 - +60 °C					
Permitted humidity	0 - 100 %					
DC connection technology	3x DC+ and 3x DC- screw terminals 2.5 - 16 mm²			4x DC+ and 4x DC- screw terminals 2.5 - 16mm² [3)]		
Mains connection technology	5-pole AC screw terminals 2.5 - 16 mm²			5-pole AC screw terminals 2.5 - 16mm² [3)]		
Certificates and compliance with standards	DIN V VDE 0126-1-1/A1, VDE AR N 4105, IEC 62109-1/-2, IEC 62116, IEC 61727, AS 3100, AS 4777-2, AS 4777-3, CER 06-190, G83/2, UNE 206007-1, SI 4777 [1)], CEI 0-21 [1)]					

[1)] This applies to Fronius Symo 3.0-3-M, 3.7-3-M and 4.5-3-M

[2)] according to IEC 62109-1.

[3)] 16 mm² without wire end ferrules. Further information regarding the availability of the inverters in your country can be found at www.fronius.com.

Figure 18 Fronius Symo inverter data sheet (Website of Fronius international, 2016)

APPENDIX 3

ELECTRICITY CONSUMPTION

Table 6 Electricity consumption (kWh)

Month	2012	2013	2014	2015	2016	Average monthly consumtion (kWh)	
1	260644	284569	230785	273135	263882	262603	
2	262596	265863	251568	244882	281629	261307.6	
3	281447	294035	266167	272625	261943	275243.4	
4	272414	286342	249411	273261	205335	257352.6	
5	259516	205780	264350	281108	258166	253784	
6	243017	202995	262504	253745	271368	246725.8	
7	259436	251207	263207	259962		258453	
8	264091	235952	247927	253194		250291	
9	262332	221191	243278	253691		245123	
10	266842	232764	251320	260657		252895.75	
11	132336	243232	257805	266873		225061.5	
12	278958	242360	261611	275592		264630.25	
	3043629	2966290	3049933	3168725	1542323	3053470.9	total

Figure 14 Electricity consumption trendlines

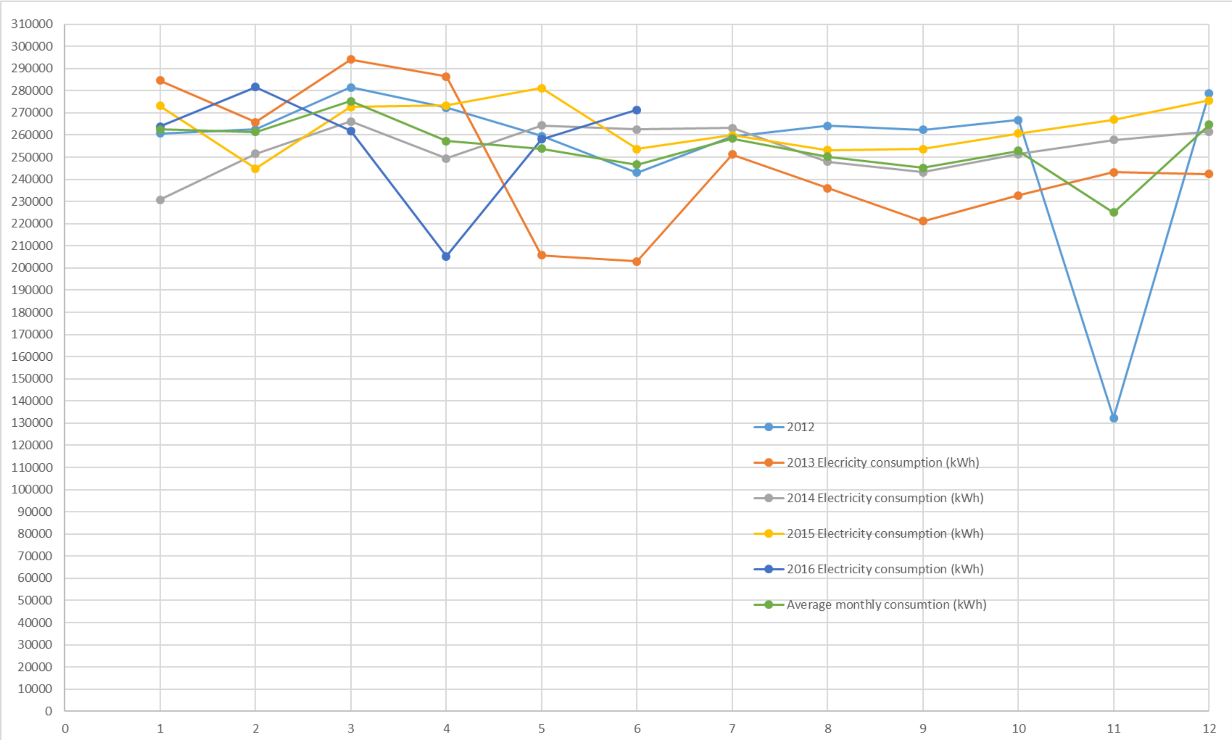


Figure 19 Electricity consumption trendlines

APPENDIX 4

GETSOLAR SIMULATION RESULTS

Table 7 Energy balance simulation for 2 collectors

Month	Production (sun) [kWh]	Radiation (sun) [kWh]	Alternative heating [kWh]	Hot water coverage [%]	Efficiency [%]
January:	**13**	44	513	2	29
February:	**41**	123	447	8	33
March:	**199**	446	333	38	45
April:	**317**	666	204	62	48
May:	**346**	707	191	65	49
June:	**356**	708	162	69	50
July:	**367**	691	174	69	53
August:	**264**	473	265	50	56
September:	**215**	403	298	42	53
October:	**93**	189	428	18	49
November:	**7**	27	504	1	27
December:	**6**	22	500	1	29
Total:	**2223**	4499	4021	36	49

Annual yield of the collectors: 556 kWh/m²

Table 8 Energy balance simulation for 3 collectors

Month	Production (sun) [kWh]	Radiation (sun) [kWh]	Alternative heating [kWh]	Hot water coverage [%]	Efficiency [%]
January:	**18**	66	510	3	27
February:	**57**	184	433	12	31
March:	**263**	670	276	50	39
April:	**410**	999	119	78	41
May:	**441**	1061	107	81	42
June:	**444**	1063	85	84	42
July:	**462**	1036	95	84	45
August:	**340**	709	193	64	48
September:	**282**	604	236	55	47
October:	**124**	283	398	24	44
November:	**10**	40	500	2	25
December:	**9**	33	496	2	26
total:	**2858**	6749	3445	46	42

Annual yield of the collectors : 476 kWh/m²

Table 9 Eco balance simulation for 2 collectors

Month	Production (sun) [kWh]	Energy savings [kWh]	[litraa]	CO2-savings [kg]
January:	13	12	**1**	4
February:	41	49	**5**	15
March:	199	206	**20**	63
April:	317	335	**33**	103
May:	346	370	**37**	114
June:	356	431	**43**	133
July:	367	422	**42**	130
August:	264	290	**29**	89
September:	215	220	**22**	68
October:	93	101	**10**	31
November:	7	8	**1**	2
December:	6	14	**1**	4
total:	2223	2459	**244**	756

Relative energy saving: 13.5%

Table 10 Eco balance simulation for 3 collectors

Month	Production (sun) [kWh]	Energy savings [kWh]	[litres]	CO2-savings [kg]
January:	18	10	**1**	3
February:	57	70	**7**	22
March:	263	275	**27**	85
April:	410	587	**58**	181
May:	441	806	**80**	248
June:	444	944	**94**	290
July:	462	862	**86**	265
August:	340	485	**48**	149
September:	282	372	**37**	114
October:	124	147	**15**	45
November:	10	2	**0**	1
December:	9	6	**1**	2
total:	2858	4568	**453**	1405

Relative energy saving: 25.2%

APPENDIX 5

KIINTEISTÖN AURINKOSÄHKÖJÄRJESTELMÄN KANNATTAVUUSLASKURIIN SYÖTETYT LÄHTÖARVOT

Sähkön kuluttajahinta eli sähköenergian ja sähkön siirron ostohinta veroineen snt/kWh	8.0	snt/kWh
Kiinteistön sähkönkulutus vuodessa kWh/v	3053470	kWh
Arvio ostosähkön hinnan noususta %/vuosi	1.0%	%/v
Aurinkosähköjärjestelmän koko tehona Wp	20000	Wp
Järjestelmän investointikustannus € (laitteet ja asennus, myös mahdollinen ALV)	€17,500	euroa
Investointituki tai kotitalousvähennys alkuinvestoinnista, %	20%	%
Oma kiinteistöarvo-, brändi- tai ympäristötuki investoinnille €	€0	euroa
Investoinnin laskentakorko, esim. pankin korkokulu	2.0%	%
Aurinkosähkön oman käytön osuus, %	60%	%
Aurinkosähkön myyntihinta verkkoon snt/kWh	6.0	snt/kWh
Invertterin vaihdon kustannus, % alkuinvestoinnista. Oletettu tapahtuvan kerran aurinkosähköjärjestelmän elinaikana 15. vuotena.	8%	%
Vuotuiset ylläpitokulut (vakuutukset, huolto tms. kulut) % alkuinvestoinnista	0.1 %	%
Aurinkosähkön vuosituotto 1 kWp:n järjestelmän sijainnin mukaan	850	kWh/kWpeak

APPENDIX 6

ASENNUSOHJEET

Järjestelmän komponentit

-4kpl Hewalex KS200 tasokeräimiä
-ZPS pumppu- ja säädinyksikkö
-18 litran paisuntasäiliö
-Lämmönsiirtoputket,n. 30m
-Anturit keräimille ja lämminvesivaraajaan
-Liittimet
-Lämmönsiirtoneste
-Akva Solar 750 lämminvesivaraaja

Keräinten asennus

Neljä keräintä tullaan asentamaan pystyyn mukaan tuleviin asennustelineisiin. Telineet voidaan varmistaa katolle vastapainojen avulla, joille ne saadaan myös helposti vatupassiin.Telineitten kiinnityksessä voidaan käyttää ruostumatonta kierretankoa. Vastapainojen ja katon väliin on hyvä laittaa pala kumimattoa, jonka reunat tulee tiivistää mahdollisten vesitaskujen syntymisen estämiseksi.

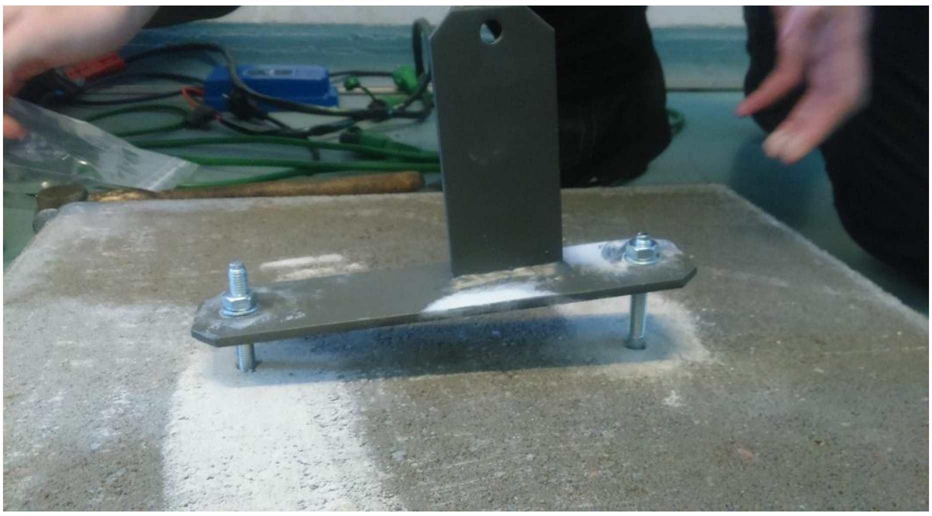


Figure 20 Keräintelineiden kulmansäätöä

Kiinnitettäessä telineitä vastapainoihin on hyvä käyttää esimerkiksi Sika Anchorfix ankkurointimassaa jolla estetään veden pääsy ja myöhemmin jäätyminen kiinnitysreikiin. Massan kovettumisen jälkeen voidaan telineet kiinnittää vastapainoihin.

Figure 21 Tiiviste- ja ankkurointimassa (Solarleap-projekti)

Figure 15 Esimerkki vastapainoista katolla (Solarleap-projekti)

Figure 16 Esimerkki telineitten asennuksesta (Solarleap-projekti)

Keräimet kiinnitetään keskenään mukana tulevilla tai muilla liittimillä, kunhan liittimet eivät ole muovisia. Optimoinnin kannalta paluuputken sijoitus tulee olla lähempänä katon reunaa ja täten lyhyemmällä matkalla takaisin varaajalle.

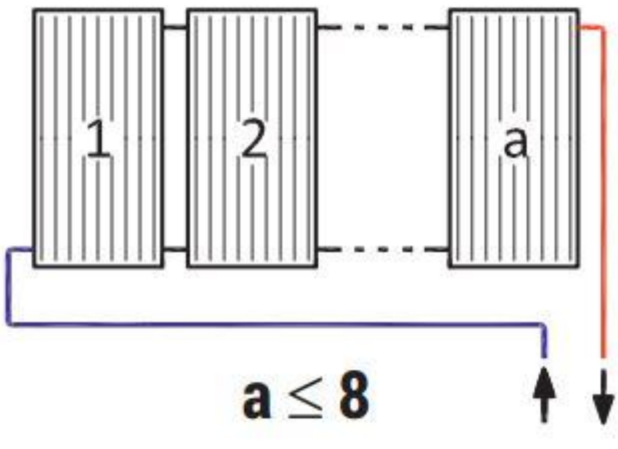


Figure 24 Keräinten liitäntä toisiinsa (Hewalex asennusohjeet)

Putkien reitti keräimiltä tekniseen tilaan

Teknisessä tilassa putket voidaan viedä kiinnikkeillä kattoa myöten kohti ulkoseinustalla sijaitsevaa betonielementtiä. Läpiviennit betoniseinän läpi tulee hoitaa asiaankuuluvalla tavalla iskuporakoneella turvallisuusseikat huomioon ottaen. Yhden putken paksuus eristeineen on noin 50mm. Ulkopuolella putket voidaan viedä kiinnikkeillä seinää myöten savupiippujen vierellä katolle.

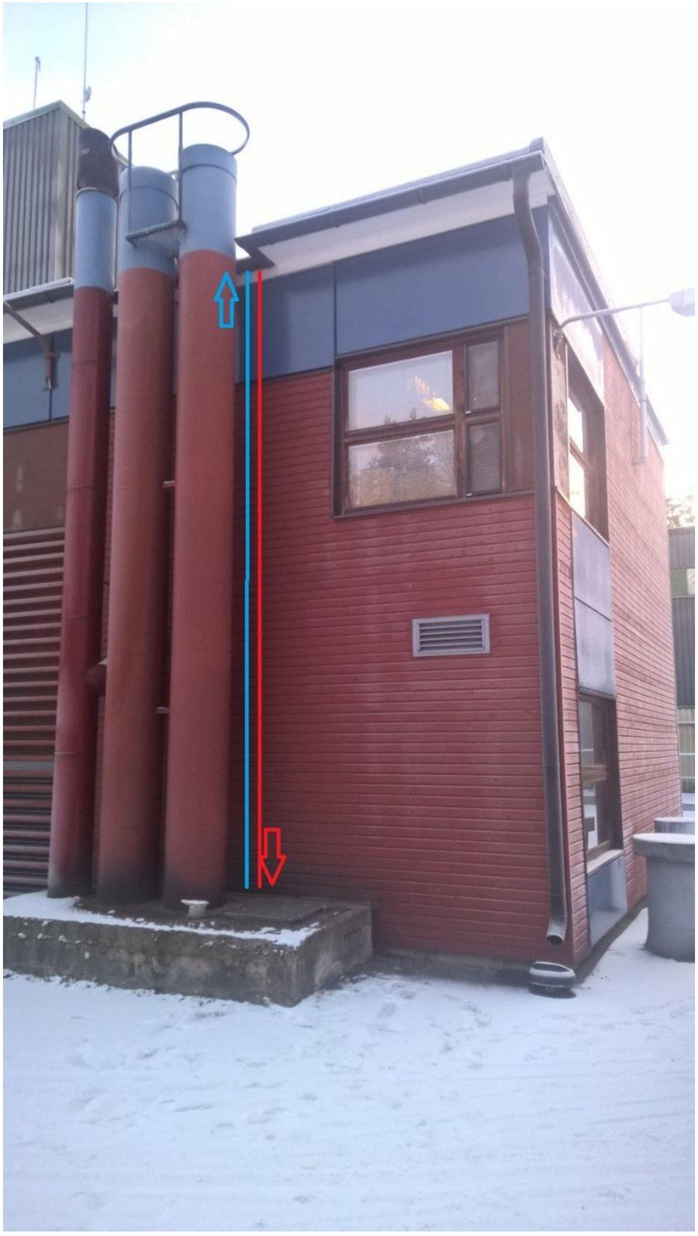
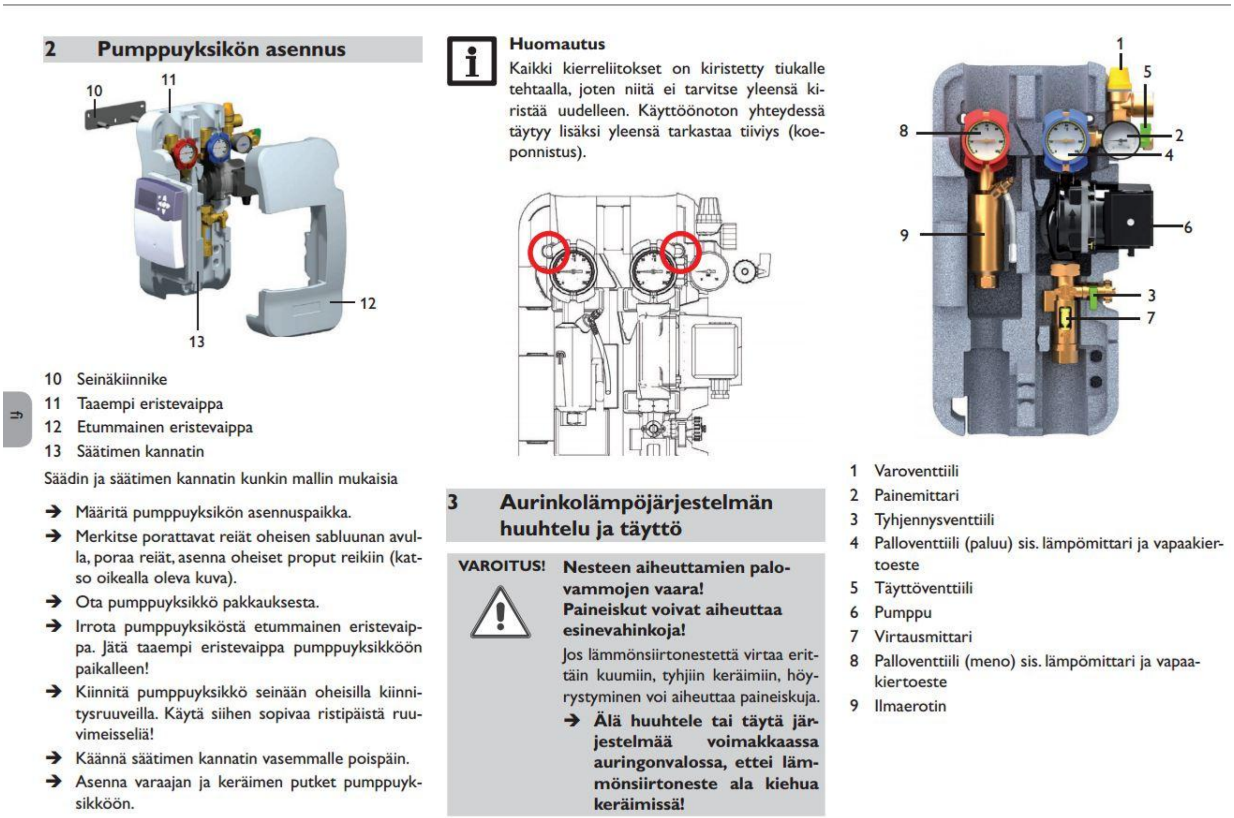


Figure 25 Esimerkki lämmönsiirtoputkien viennistä katolle

Liitännät teknisessä tilassa

Lämmönsiirtoputket kiinnnitetään pumppu- ja säädinyksikköön josta liitännät varaajalle voidaan tehdä eristettyjä kupariputkia käyttäen.



2 Pumppuyksikön asennus

10 Seinäkiinnike
11 Taaempi eristevaippa
12 Etummainen eristevaippa
13 Säätimen kannatin

Säädin ja säätimen kannatin kunkin mallin mukaisia

- ➔ Määritä pumppuyksikön asennuspaikka.
- ➔ Merkitse porattavat reiät oheisen sabluunan avulla, poraa reiät, asenna oheiset propit reikiin (katso oikealla oleva kuva).
- ➔ Ota pumppuyksikkö pakkauksesta.
- ➔ Irrota pumppuyksiköstä etummainen eristevaippa. Jätä taaempi eristevaippa pumppuyksikköön paikalleen!
- ➔ Kiinnitä pumppuyksikkö seinään oheisilla kiinnitysruuveilla. Käytä siihen sopivaa ristipäistä ruuvimeisseliä!
- ➔ Käännä säätimen kannatin vasemmalle poispäin.
- ➔ Asenna varaajan ja keräimen putket pumppuyksikköön.

Huomautus
Kaikki kierreliitokset on kiristetty tiukalle tehtaalla, joten niitä ei tarvitse yleensä kiristää uudelleen. Käyttöönoton yhteydessä täytyy lisäksi yleensä tarkastaa tiiviys (koeponnistus).

3 Aurinkolämpöjärjestelmän huuhtelu ja täyttö

VAROITUS! Nesteen aiheuttamien palovammojen vaara! Paineiskut voivat aiheuttaa esinevahinkoja!
Jos lämmönsiirtonestettä virtaa erittäin kuumiin, tyhjiin keräimiin, höyrystyminen voi aiheuttaa paineiskuja.
➔ **Älä huuhtele tai täytä järjestelmää voimakkaassa auringonvalossa, ettei lämmönsiirtoneste ala kiehua keräimissä!**

1 Varoventtiili
2 Painemittari
3 Tyhjennysventtiili
4 Palloventtiili (paluu) sis. lämpömittari ja vapaakiertoeste
5 Täyttöventtiili
6 Pumppu
7 Virtausmittari
8 Palloventtiili (meno) sis. lämpömittari ja vapaakiertoeste
9 Ilmaerotin

Figure 26 Pumpun asennus (Resol, 2016)

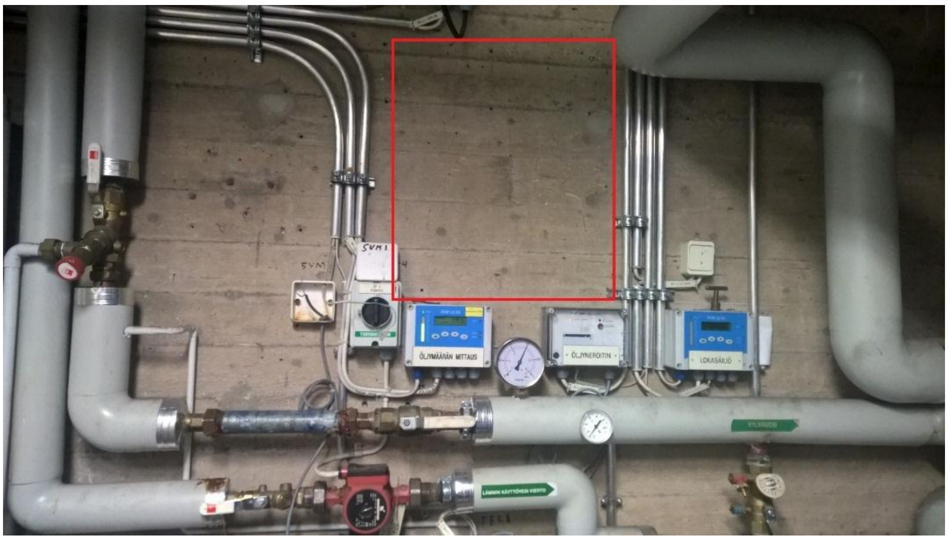


Figure 17 Pumppuyksikön mahdollinen sijainti (Kirjoittaja, 2016)

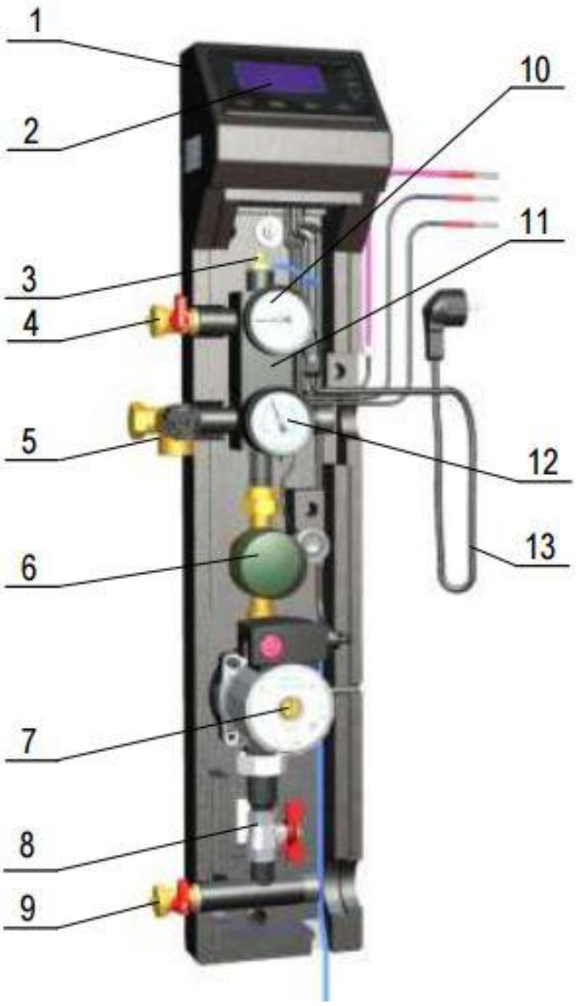


Figure 28 Pumppuyksikkö (Hewalex asennusohjeet)

1. Pumppuyksikön kuori
2. Ohjainyksikkö neljällä sensorilla
3. Automaattinen venttiili
4. Paineenalennusventtiili
5. Turvaventtiili 5baaria
6. Elektroninen virtausmittari
7. Pumppu
8. Palloventtiili
9. Paineenalennusventtiili
10. Lämpötilamittari 0-120°C
11. Ilmanerotin integroidulla venttiilillä
12. Painemittari
13. Virtajohto

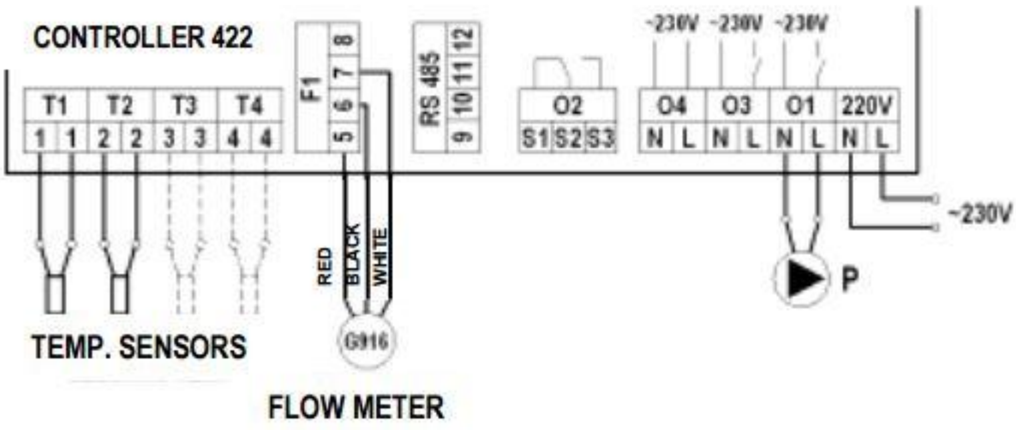


Figure 29 Ohjainyksikön sähköliitännät (Hewalex asennusohjeet)

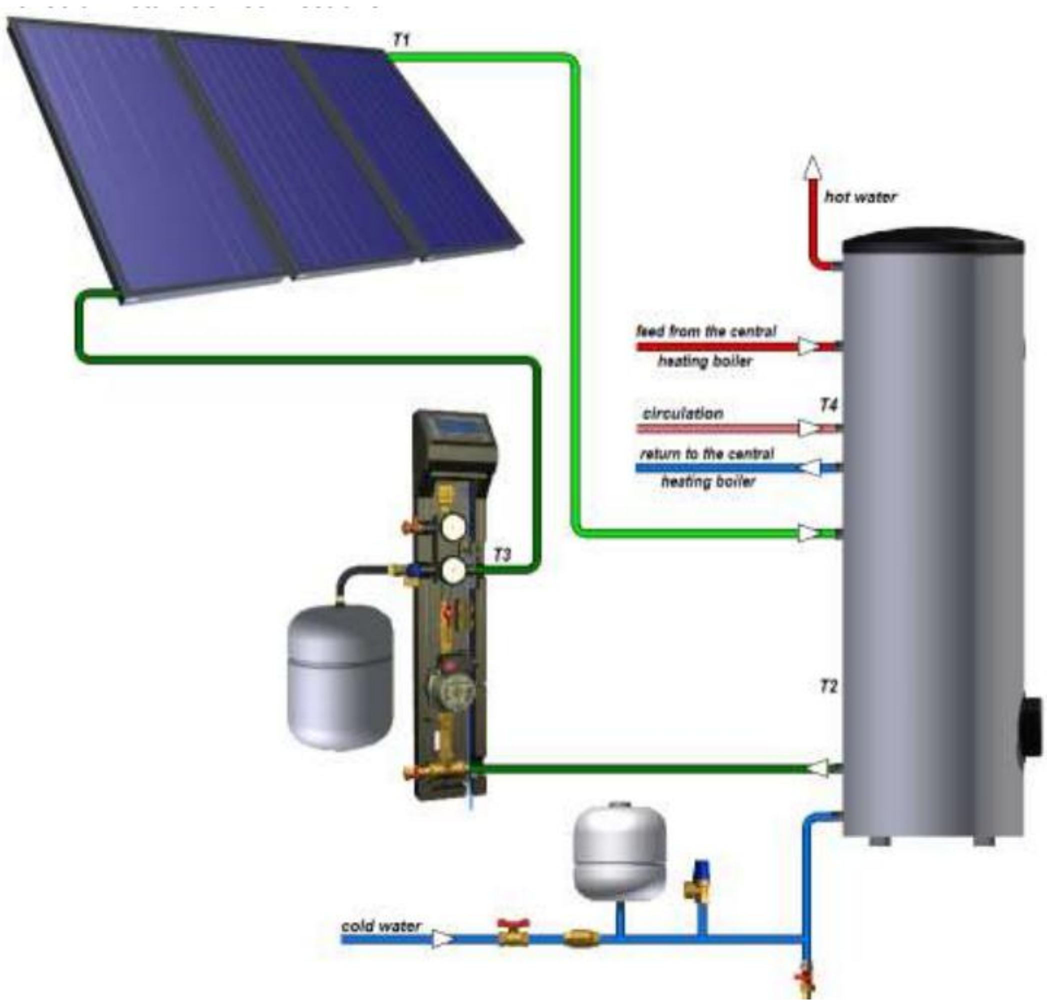
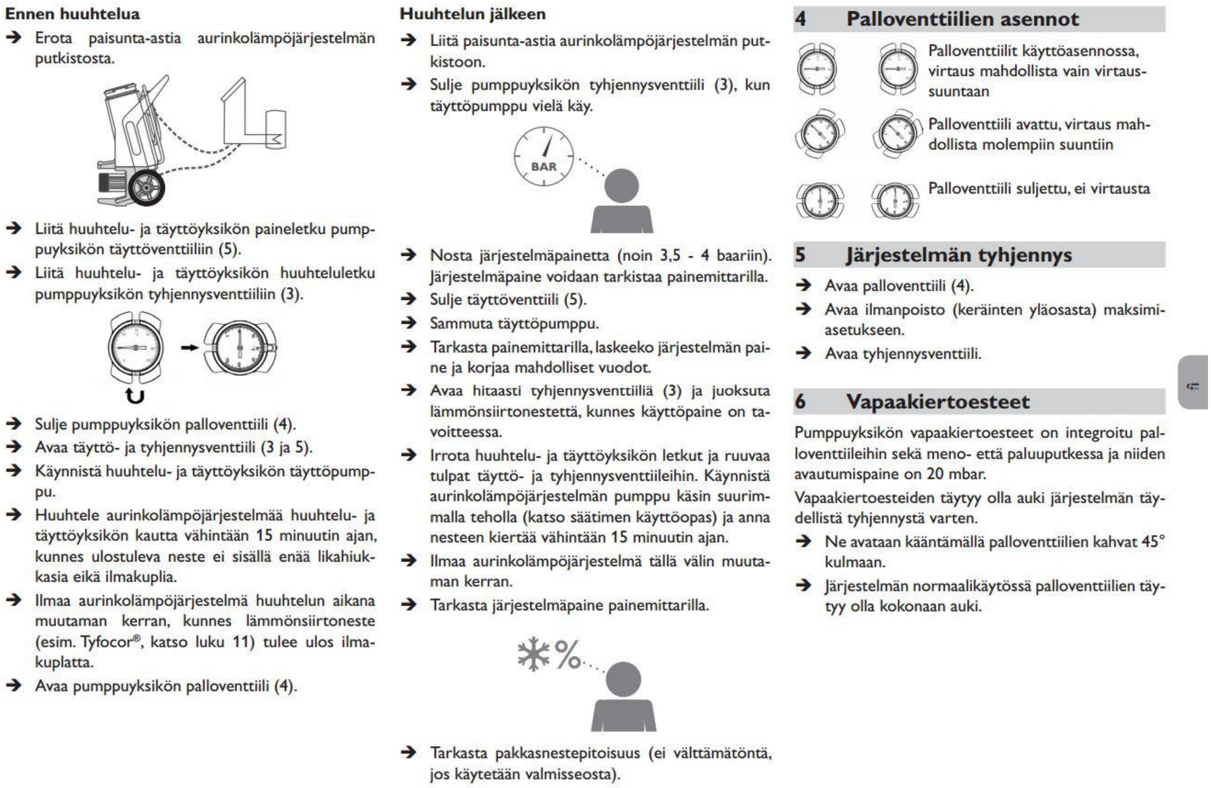


Figure 30 Liitännät lämminvesivaraajaan (Hewalex asennusohjeet)

Järjestelmän käyttöönotto

Järjestelmää täytettäessä tulee samanaikaisesti tarkkailla keräimiä katolla mahdollisten vuotokohtien havaitsemiseksi. Mikäli keräimien liitännät on kiristetty liiallista voimaa käyttäen on tämä saattanut johtaa keräimen sisäisen putkiston murtumiseen, kuten kuvassa 32 jossa lämmönsiirtoneste vuotaa keräimen sisään.



Ennen huuhtelua

➔ Erota paisunta-astia aurinkolämpöjärjestelmän putkistosta.

➔ Liitä huuhtelu- ja täyttöyksikön paineletku pumppuyksikön täyttöventtiiliin (5).

➔ Liitä huuhtelu- ja täyttöyksikön huuhteluletku pumppuyksikön tyhjennysventtiiliin (3).

➔ Sulje pumppuyksikön palloventtiili (4).

➔ Avaa täyttö- ja tyhjennysventtiili (3 ja 5).

➔ Käynnistä huuhtelu- ja täyttöyksikön täyttöpumppu.

➔ Huuhtele aurinkolämpöjärjestelmää huuhtelu- ja täyttöyksikön kautta vähintään 15 minuutin ajan, kunnes ulostuleva neste ei sisällä enää likahiukkasia eikä ilmakuplia.

➔ Ilmaa aurinkolämpöjärjestelmä huuhtelun aikana muutaman kerran, kunnes lämmönsiirtoneste (esim. Tyfocor®, katso luku 11) tulee ulos ilmakuplatta.

➔ Avaa pumppuyksikön palloventtiili (4).

Huuhtelun jälkeen

➔ Liitä paisunta-astia aurinkolämpöjärjestelmän putkistoon.

➔ Sulje pumppuyksikön tyhjennysventtiili (3), kun täyttöpumppu vielä käy.

➔ Nosta järjestelmäpainetta (noin 3,5 - 4 baariin). Järjestelmäpaine voidaan tarkistaa painemittarilla.

➔ Sulje täyttöventtiili (5).

➔ Sammuta täyttöpumppu.

➔ Tarkasta painemittarilla, laskeeko järjestelmän paine ja korjaa mahdolliset vuodot.

➔ Avaa hitaasti tyhjennysventtiiliä (3) ja juoksuta lämmönsiirtonestettä, kunnes käyttöpaine on tavoitteessa.

➔ Irrota huuhtelu- ja täyttöyksikön letkut ja ruuvaa tulpat täyttö- ja tyhjennysventtiileihin. Käynnistä aurinkolämpöjärjestelmän pumppu käsin suurimmalla teholla (katso säätimen käyttöopas) ja anna nesteen kiertää vähintään 15 minuutin ajan.

➔ Ilmaa aurinkolämpöjärjestelmä tällä välin muutaman kerran.

➔ Tarkasta järjestelmäpaine painemittarilla.

➔ Tarkasta pakkasnestepitoisuus (ei välttämätöntä, jos käytetään valmisseosta).

4 Palloventtiilien asennot

Palloventtiilit käyttöasennossa, virtaus mahdollista vain virtaussuuntaan

Palloventtiili avattu, virtaus mahdollista molempiin suuntiin

Palloventtiili suljettu, ei virtausta

5 Järjestelmän tyhjennys

➔ Avaa palloventtiili (4).

➔ Avaa ilmanpoisto (keräinten yläosasta) maksimiasetukseen.

➔ Avaa tyhjennysventtiili.

6 Vapaakiertoesteet

Pumppuyksikön vapaakiertoesteet on integroitu palloventtiileihin sekä meno- että paluuputkessa ja niiden avautumispaine on 20 mbar.

Vapaakiertoesteiden täytyy olla auki järjestelmän täydellistä tyhjennystä varten.

➔ Ne avataan kääntämällä palloventtiilien kahvat 45° kulmaan.

➔ Järjestelmän normaalikäytössä palloventtiilien täytyy olla kokonaan auki.

Figure 31 Järjestelmän huuhtelu ja käyttöönotto (Resol, 2016).

Figure 32 Esimerkki viallisesta keräimestä täytön yhteydessä (Kirjoittaja, 2015).

Koska öljykattilat toimivat omien termostaattiensa varassa, järjestelmän liittämisen tulisi olla suhteellisen yksinkertaista ja molemmat voivat toimia itsenäisesti. Näin ollen aurinkojärjestelmän esilämmittämän veden lämpötila määrittää suoraan kuinka paljon öljypoltin tulee käymään.