LECo - Feasibility study

–PV-System for dairy farm

ILPO WENNSTRÖM'S FARM

Einar Nystedt 2019
Centria TKI

1. Introduction

This report reviews the techno-economic feasibility of utilizing a PV-system for energy production on a large dairy farm in Sykäräinen Finland. The viability of the PV-system is highly dependent on the correlation between the consumption and production profiles. This feasibility study examines the dairy farm's hourly electricity demand and the coverage of the potential solar energy generation in different scenarios.

In Finland, a PV-system is most profitable when the generation only displaces imported electricity rather than creating surplus energy. Acquiring one kWh electricity from the grid costs approximately 0.10-0.15 € including taxes and grid costs. When exporting electricity to the grid, the producer generally only receives slightly less than the current hourly SPOT-price, which is only around 30-35% off what the imported electricity costs. Thus far, Finland has no tariff support for small producers.

The goal with the PV-system is also to improve the farms energy self-sufficiency and to reduce their carbon footprint. Wennström's farm is currently importing 100% of the electricity utilized. Finland's CO_2 emissions from the electricity generation mix was in 2017 95 kg CO_2 per MWh. Calculated with the average production mix emissions, Wennström's farms electricity-based emissions were 28.2 tons of CO_2 in 2017.

Wennström's farm utilizes milking robots and the annual energy consumption of the robots ranges from 200 to 500 kWh per cow. The farms total electrical energy consumption in 2017 was 297 MWh; this also includes the ground source heating for the 5800 m^2 farm. The use of electricity during summer months is rather significant; there for a PV-system may be a profitable investment.

This analysis will estimate the viability of different size PV-configurations from 30 to 70 kWp. The barn roof-slopes are roughly facing east and west and they will be considered as possible mounting points for the panels. The analysis will also consider ground-mounted panels, in an optimal angle facing south.

2. About the LECo-project

The LECo project supports small communities in becoming self-sufficient regarding energy. The project aims at raising awareness about energy efficiency and the possibilities to use locally available renewable energy, such as wind, solar and hydropower, as well as side streams from industry, households and agricultural origin.

3. Wennström's Farm

Wennström's farm is a large dairy farm that is situated in Sykäräinen. The farm employs three workers in addition to the Wennström's.

Sykäräinen is a village in Central Ostrobothnia. Sykäräinen is located in Western Finland and is a part of the municipality of Toholampi.

The municipality has a population of 3,141 and covers an area of 617 km2 of which 8.45 km2 is water. The population density is 5.16 inhabitants per km2. Neighbouring municipalities are Kannus, Kokkola, Lestijärvi and Sievi.

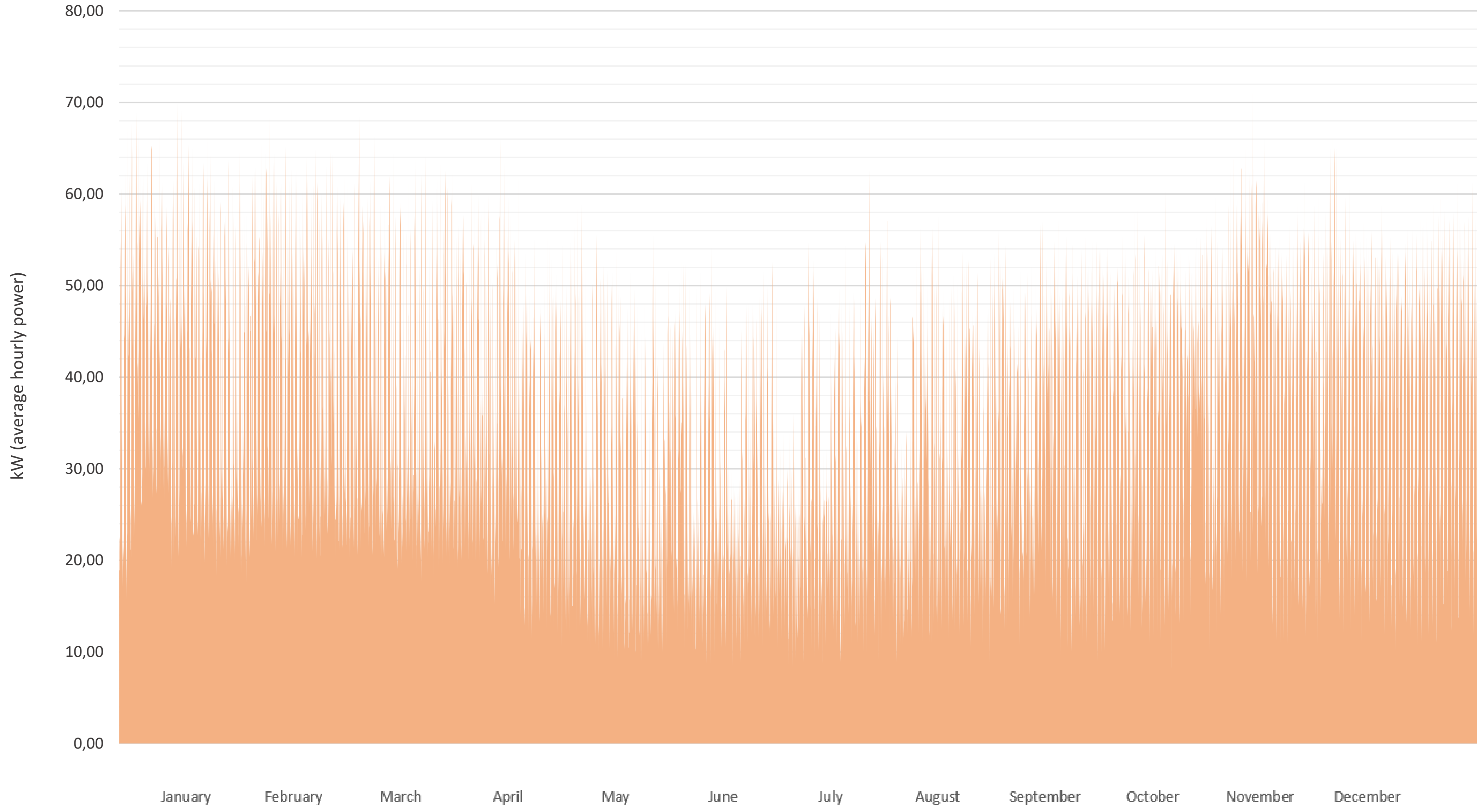
Wennström's farms owner is interested in installing solar panels on the barn roof to cover some of the energy demand from the milking robots and other loads.

The Rooftop area is approx. 2700 m2 and is at an angle of 12 degrees. The roof is built from sheet metal and the orientations are directed roughly to the west (260°) and east (80°). The rooftop material is suitable for panel installations.

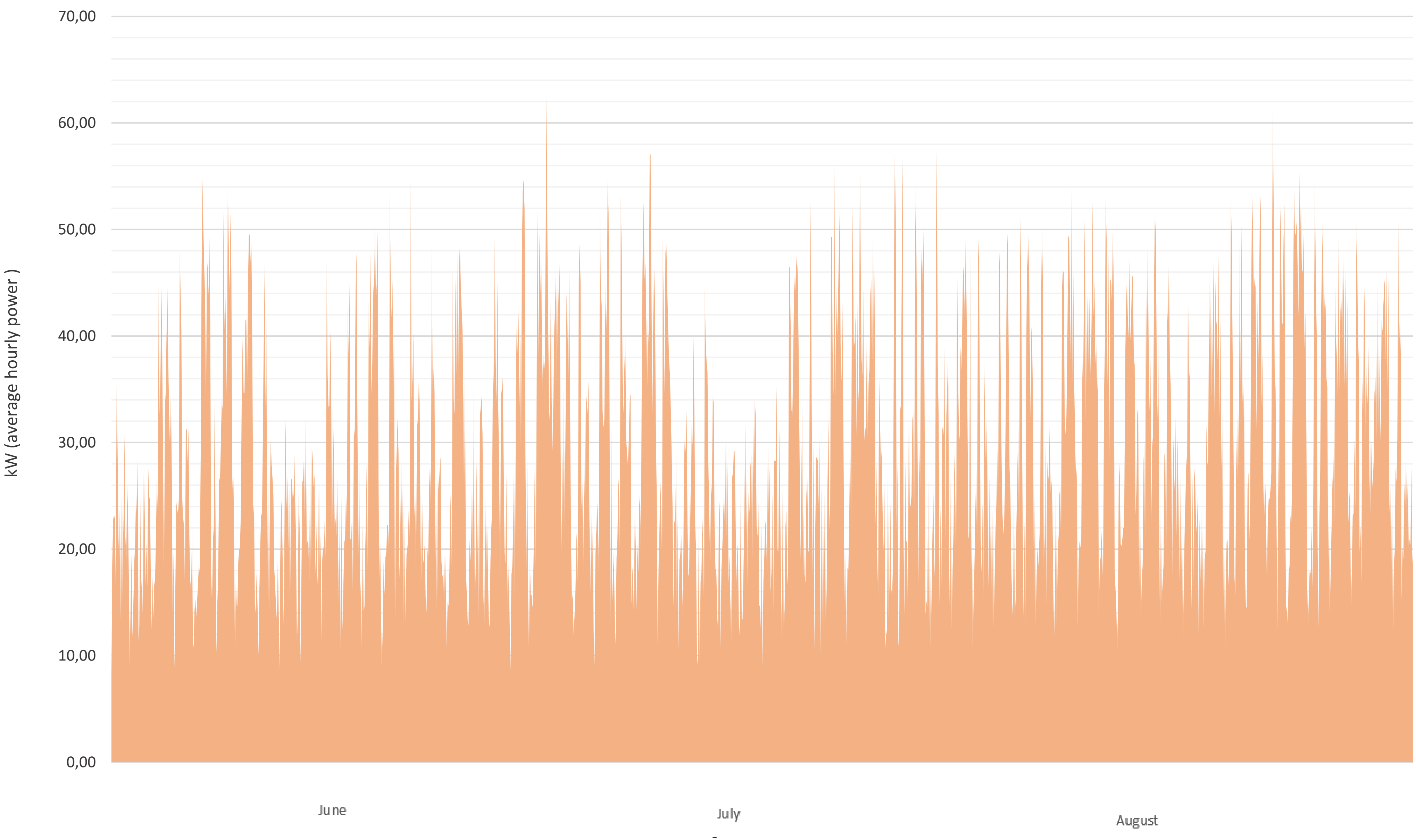
3.1 Energy consumption

The farms total electrical energy consumption in 2017 was 297 MWh with a peak load of 71.4 kW, which occurred November. The lowest average hourly power was 7.64 kW and occurred in May. The compound is heated with a ground source heat pump and the base load in winter times is about 17 kW. The base consumption during summertime is in average 9 kW lower than in winter.

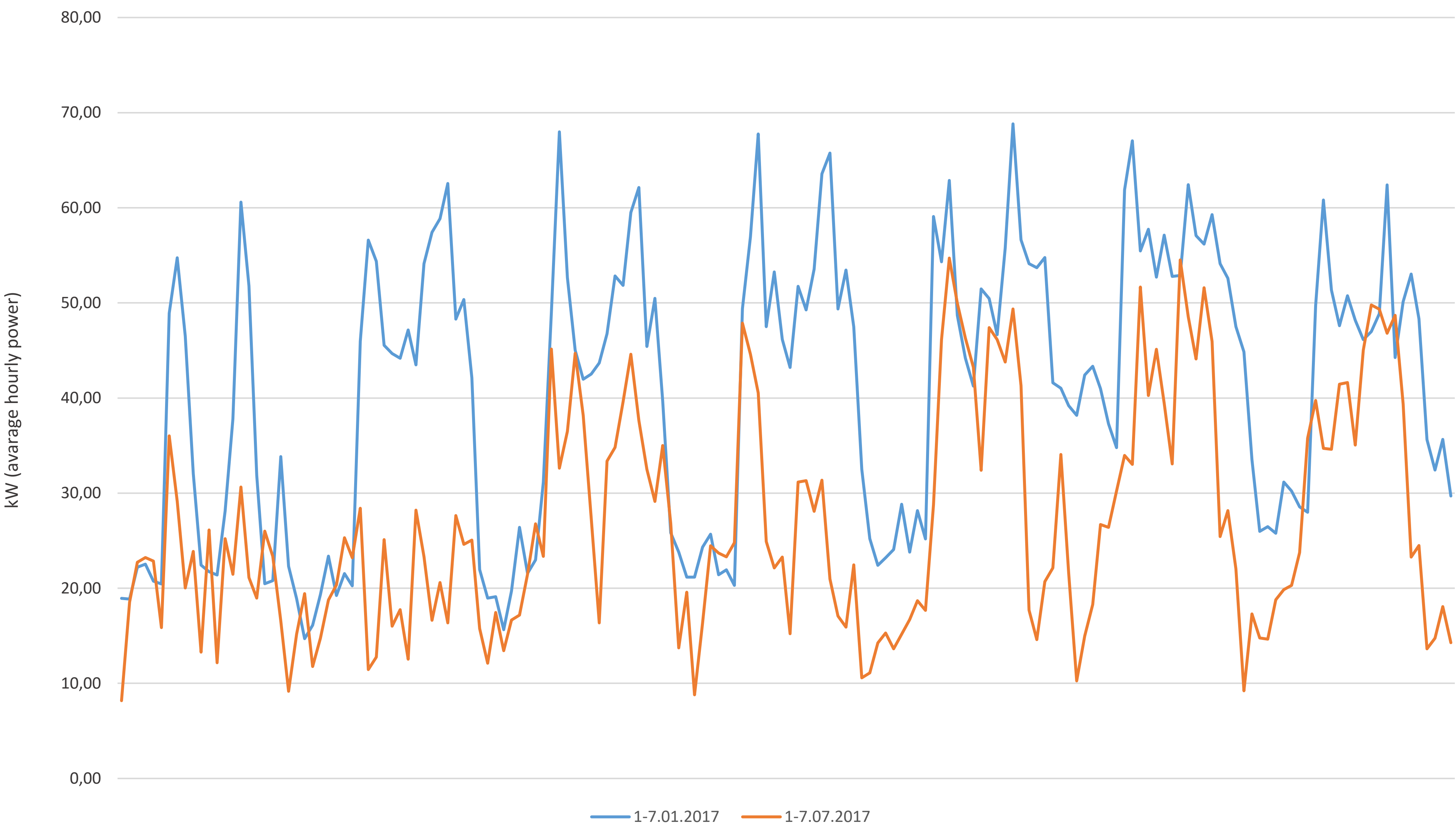
Electricity consumption profile 2017



Electricity consumption profile, July-August 2017



Electricity consumption profile 2017

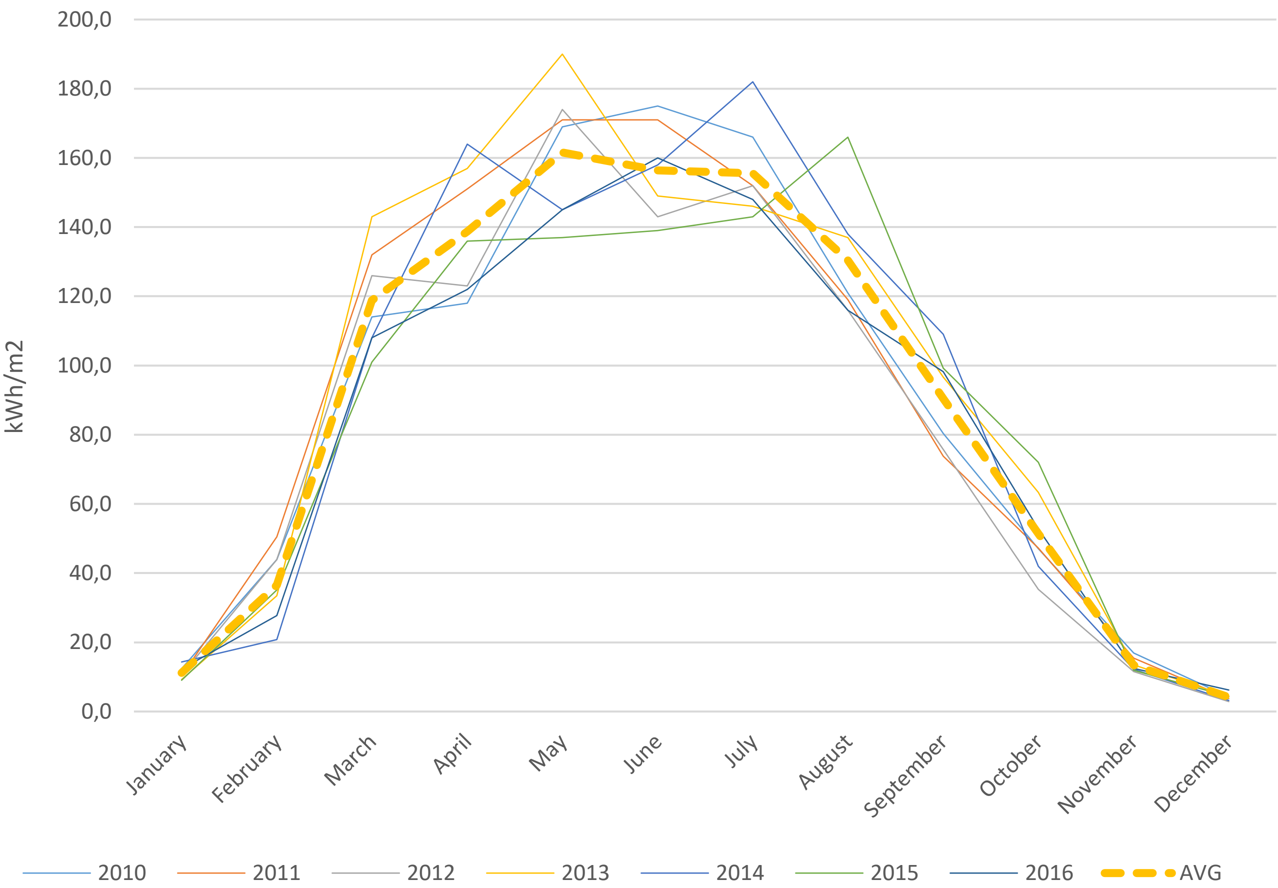


4. Solar potential on Wensström's farm

The implementation of PV-systems in Finland has been relatively slow mainly because of the high price of PV-systems until recent years, but also because the Finnish feed-in tariff system does not apply to small-scale PV-systems.

Despite Finland's long and dark winters, the area is quite well suited for PV-energy production. The annual irradiation difference between the Nordic countries and e.g. Germany is not that significant. The annual irradiation in Helsinki is approximately 1120 kWh/m2 and in Berlin, it is 1250 kWh/m2.

The average monthly irradiation on Wennström's farm (kWh/m2):



Source: Photovoltaic Geographical Information System

The graph describes the monthly sum and average of the solar radiation energy (kWh/m2) that hits one square meter of a plane facing in the direction of the equator, at the inclination angle of 45°. The annual total irradiation on Wennström's farm is 1069 kWh per m2.

5. Modeling the PV-system production

The model considers five different sized PV-configurations from 30 to 70 kWp. The results shows the annual energy production, the production and consumption profile correlation on an hourly basis, and the export-import balance.

The solar radiation data used in the modeling are based on climate reanalysis data, in particular the PVGIS-ERA5-data set. The European Centre has made the PVGIS-ERA5 data set available for Medium-Range Weather Forecast.

Modeled annual PV-system production:

PV-system:	South 180° (MWh):	West 260° (MWh):	East 80° (MWh):
30 kWp	24,3	18,9	18,1
40 kWp	32,4	25,2	24,2
50 kWp	40,5	31,5	30,2
60 kWp	48,6	37,8	36,2
70 kWp	56,7	44,0	42,3

Annual own consumption of production:

PV-system:	South 180° (MWh):	West 260° (MWh):	East 80° (MWh):
30 kWp	24,0	18,8	18,0
40 kWp	31,3	24,8	23,9
50 kWp	38,1	30,7	29,4
60 kWp	44,1	36,1	34,7
70 kWp	49,4	41,2	39,7

Annual export to the grid:

PV-system:	South 180° (MWh):	West 260° (MWh):	East 80° (MWh):
30 kWp	0,3	0,1	0,1
40 kWp	1,1	0,3	0,3
50 kWp	2,4	0,8	0,7
60 kWp	4,5	1,6	1,5
70 kWp	7,3	2,8	2,6

Annual import from the grid:

PV-system:	South 180° (MWh):	West 260° (MWh):	East 80° (MWh):
30 kWp	273,0	278,2	279,0
40 kWp	265,7	272,2	273,1
50 kWp	258,9	266,3	267,6
60 kWp	252,9	260,9	262,3
70 kWp	247,6	255,8	257,3

Modeled with crystalline silicon panels and a system loss of 14%. Panels at 12° slope (west and east) or 45° slope (south).

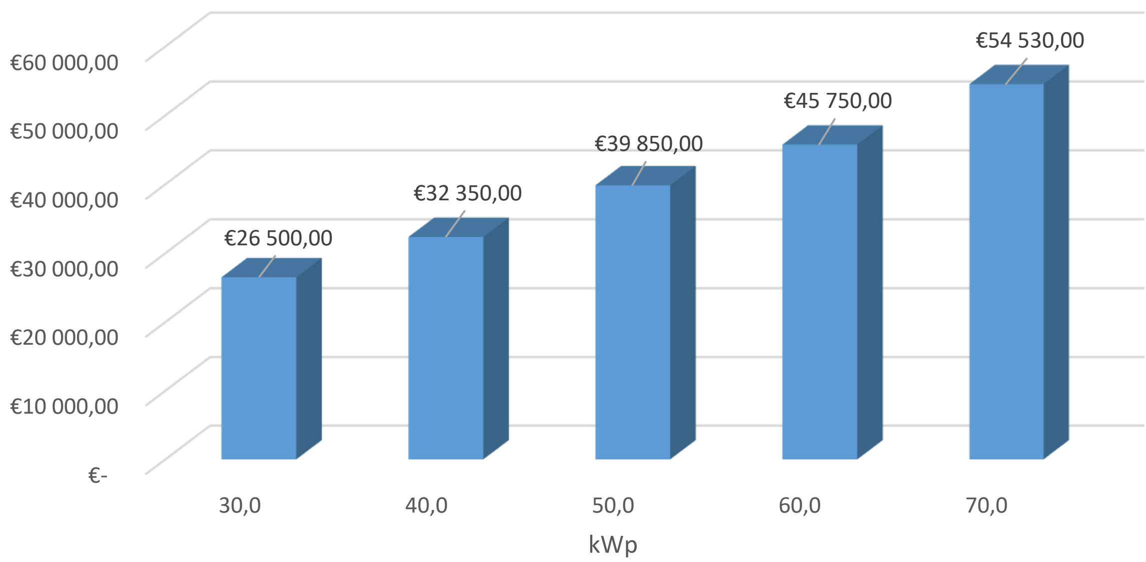
6. Investment calculations

The profitability calculations consider the following parameters:

Electricity purchase price	40,0 €/MWh
Grid costs	20,0 €/MWh
Tax and service security fee	22,5 €/MWh
Estimated annually electricity price increase	0,2 %
Estimated electricity sale price	35,0 €/MWh
Finance rate	2,0 %
Annual return requirement	0,0 %
Interest of investment	2,0 %
Annual maintenance costs	0,5 % of initial investment
Annual system efficiency decline	-0,5 %
Inverter replacement costs (1/life cycle)	10 % of initial investment
Investment aid ELY-keskus	40 %
System life cycle	30 years

The system investment costs that are used in the calculations are based on budget tenders and are in line with reported average prices. Prices includes all the PV-system components, mounting accessories and the installation of the system including the connection to the grid.

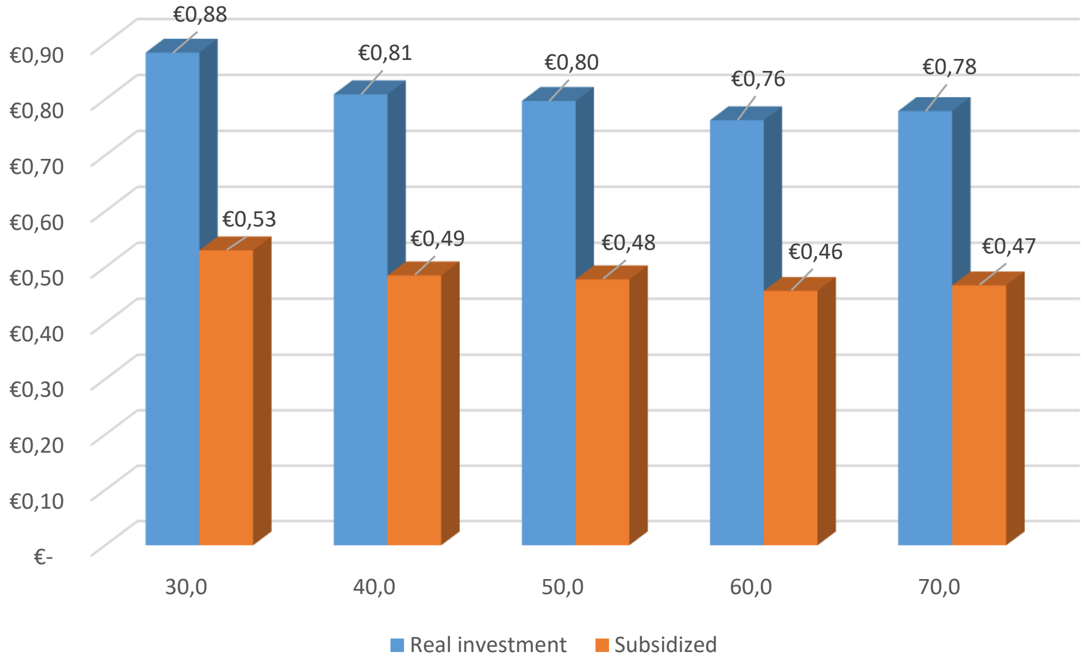
Investment costs:



The Finnish Centre for Economic Development, Transport and the Environment (ELY-keskus) grants a 40% investment aid to farms for renewable energy projects. The requirements are that the PV-system size is at least 14 kWp and system costs should stay under 1 300 €/kWp when the PV-system is under 100 kWp. When the size of the system exceeds 100 kW, the approved costs are 950 €/kW.

Investment costs when the investment aid is taken into account:

Relative investment costs (€/W) for the different setups:



7. Investment calculations

PV-system facing west at an inclination angle of 12°. This represents an actual barn-roof mounting at Wennström's farm.

Profitability without investment aid for the different setups:

PV-system	Investment	Life cycle costs	Net asset value	Payback years
30 kWp	26 500 €	6 625,0	929,0	28
40 kWp	32 350 €	8 087,5	4 785,	24
50 kWp	39 850 €	9 962,5	6 234,0	24
60 kWp	45 750 €	11 437,5	9 333,0	23
70 kWp	54 530 €	13 632,5	8 563,0	24

Profitability including investment aid (40%) for the different setups:

PV-system	Investment	Life cycle costs	Net asset value	Payback years
30 kWp	15 900 €	6 625,0	11 321,0	14
40 kWp	19 410 €	8 087,5	17 472,0	11
50 kWp	23 910 €	9 962,5	21 861,0	11
60 kWp	27 450 €	11 437,5	27 275,0	10
70 kWp	32 718 €	13 632,5	29 947,0	11

Investment calculations were carried out utilizing a profitability calculator implemented during the Aalto University led Finsolar project. For more information visit: http://www.finsolar.net

8. Conclusions

None of the reviewed PV-systems would be feasible without investment support. Even with the 40% ELY-investment support, none of the systems reached a payback period of less than 10 years.

The slight increase in the payback time regarding the 70 kW is due to the fact that when production increases, the share of self-consumption decreases and the overall profitability decreases.