The Economy and Possibility of Energy Community in Finnish Solar Energy Production

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***Abstract*—The amount of solar energy production in the electricity distribution networks is increasing. This is due to the technology conventionalization, which in turn has led to solar panels becoming more affordable. The aim of this study was to analyse real-life domestic electricity consumption to determine weather changes in current Finnish legislation could enable new, economic possibilities in the use of solar power. The hypothesis was that a group of individual solar power producers could benefit from a common system as compared to each group member having a solar production system of their own. In Finland, private households benefit from solar energy production via savings from both energy and transmission costs, as well as, taxes included in these costs. It is economical to install and utilize solar energy even though the solar energy price is higher than that of fossil fuels. In this study, the economy of energy communities with bigger solar panel units were compared with individual households with small-scale solar production units. As conclusion, the study results indicate that the overall economy of solar energy would be better, if the solar panels were installed in bigger units to the network. However, this possibility requires that energy communities would be legally allowed in Finland.**

Keywords—solar energy, energy community, economy

I. INTRODUCTION

Solar energy has increased popularity during the last years in Finland, although the share of solar energy nationally is only around 0,07 per cent in total energy production [1]. However, the aim due to climate change should be increasingly towards the renewable energies whilst reducing the use of fossil fuels [2]. To reduce carbon emissions in European Union, the EU legislation is currently in transition towards removing legal, bureaucratic and technical barriers that have hindered the transition towards the use of renewable energy sources [3]. Furthermore, there is strong indication that the private sector representatives in Finland would be increasingly interested in investing into renewable energies such as solar energy [2,4,5]. On contrast, fossil fuels are still subsidized in the world by 5,8 per cents out of Gross Domestic Product globally [2]. Therefore, Finnish government should aim at promoting the use of renewable energies on long term, since the desirable changes in the energy production will be led by private investments [2]. Currently, private households and other private sector representatives invest into solar energy mainly because solar energy is becoming more affordable and available [5].

In Finland, private households pay about 15 sents per kWh of the electricity consumed [6]. The price consists of three main components that account roughly one third each. The price components are the price of energy, transmission costs and taxes. [7] By producing and using solar energy, a private household can avoid paying the majority of these price components to the electricity provider. The only downside is that it is relatively expensive to purchase a small solar energy production unit [8]. Therefore, this study case is aimed at researching whether a larger, centralized and shared solar production unit could be financially beneficial to both the individual households, as well as, to the electricity network.

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II. MATERIALS AND METHODS

A. *Solar energy production modelling*

In Finland, the solar energy production varies strongly depending on the time of the day and the time of the year. However, the summertime with long daylight hours, along with favorable outdoor temperatures, make the Finnish climate more favorable to solar energy production than is commonly thought. [5] In this study, the daily and seasonal variation of the solar radiation was considered by creating a model where the hourly production of the solar panels (in kWh) could be studied. Additionally, the solar energy production is dependent on the size of the solar panels (kW), as well as, the cloudiness of the day. Therefore, the cloudiness was modelled, using a random factor, so that the utilisation period of the solar power was around 800 hours in a year.

B. *Household electricity consumption cases*

In this study, the household electricity consumption was analysed using hourly electricity consumption of six real-life household cases [9,10,11,12,13]. Each of the electricity consumption cases represents an example of domestic electricity and buildings in the South Savo (Finland) area. The study group was purposely chosen heterogonous in building size, number of inhabitants, heating system and type of use. The studied building sizes varied between 67 to 167 m^2, the number of inhabitants varied between 2 and 5, and the heating systems represented were electric heating, district heating and thermal heating. Four of the study cases were private family houses. Additionally, the fifth study case was a household with a separate livestock building connected to the households' electric consumption network. And lastly, the sixth study case was a privately-owned summer cottage. Both fifth and sixth study cases are typical to South Savo area and are therefore of value to the study.

The common nominator for the study household cases was that they do not yet have solar energy production. Furthermore, in this study they are considered as neighbors to each other, when in real life they are not situated next to each other. The shared solar electricity system would require for them to be neighbors to be able to utilise the solar electricity directly on site.

The hourly production model for solar radiation and production (described in section A) could be compared with the electricity consumption profile of the study case households. Every household in Finland can obtain its' own electricity consumption as hourly data. The data is created by a remote-controlled energy consumption meters, which are obligatory in Finland [14]. By comparing these two sets of data, it was possible to determine how much of the produced solar energy each study case would be able to utilize, and what portion of energy produced should to be sold to the electricity network.

C. Solar power system price components considered

The investment price for the solar power production depends on the size of the production unit. The price of the solar system (Euros per kW) decreases with the increase in system size. The investment price for small scale units is presented in Figure 1, and for larger scale units in Figure 2. The system prices represent the prices typical for South Savo area [4, 15].

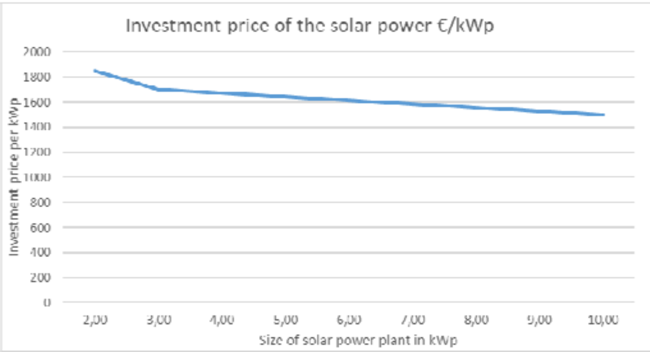

Fig. 1. The investment price for small scale solar power plant in Euros per kWp according to the size of the solar unit in kW [4, 15].

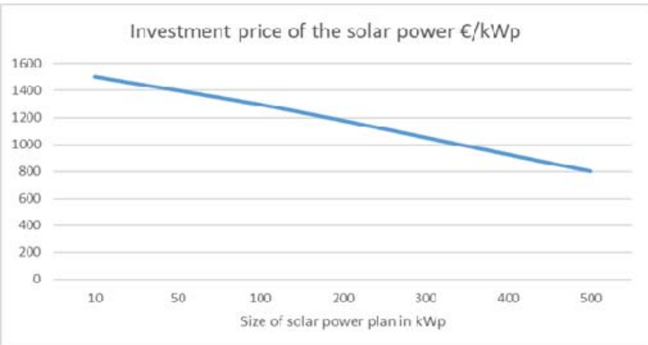

Fig. 2. The investment price for the large scale solar power plant in Euros per kWp according to the size of the solar unit in kW [4, 15].

The electricity price for the domestic users in Finland includes three price components: the energy costs, the transmission costs and taxes [16]. Each of these components represents about one third in the total price, which the domestic electricity user pays for the consumed electricity. Furthermore, each of these price components consist of both flat rate and consumption dependent part [16]. The flat rate share of the costs must be paid in any case. Therefore, the economic value of solar energy for the households can be considered as 8,5 sent/kWh [4]. Additionally, the maintenance costs for the solar panels in this study have been considered as 1,5 sent/ kWh [17]. Furthermore, the economic value of the solar energy may be considered as 3,5 sent/kWh for the domestic solar producer, when the energy is excess and is sold back to the network [18]. The total cost of the electricity, provided by the electricity network, may be considered as 15 sent/kWh [6]. In the calculations, however, the value of produced solar energy is considered as 8,5 sent/kWh, since the difference is the flat rate [7].

The solar energy produced and utilized in a household naturally reduces the amount of electricity needed and bought from the electricity provider via the electricity network. Furthermore, due to energy production taxation in Finland, the share of the electricity that needs to be sold to the network, should be as low as possible [17]. The household producing solar energy should not produce excess energy, since it cannot benefit from the sold energy economically. The price of solar energy, when sold to the network, is less than half of that of the energy that the household uses itself to replace purchasable electricity. [18]

The size of the solar power unit for household users depends on the electricity consumption profile. The critical issue is to match the consumption and production as well as possible. As stated before, the solar electricity sold back to network is not profitable for the household producer due to the lower selling price. Therefore, in this study, the solar panel size was chosen so that at least 70 per cent of the produced energy could be used in the household, and the remaining 30 per cent could be sold back to the electricity network [16]. However, all the study cases were set with a minimum of 2 kW solar system.

III. RESULTS

The aim of this study was to research a group of households to determine if an energy community in solar energy production would be more economically favorable for the households as compared to each having an individual solar panel system of their own. To make the needed comparison possible, both cases and their results are demonstrated in the following.

A. Household cases with individual solar energy systems

The study group of six South Savo household cases are presented in Table I, where they are numbered from 1 to 6 as individual consumption cases. The Table I includes electricity consumption, maximum power, building surface area and source of heating. [9,10,11,12,13].

TABLE I. HOUSEHOLD CASES ANALYSED IN THE STUDY

Case	***Yearly electricity consumption***	***Maximum power***	***Surface area***	***Heating system***
1	21 554 kWh	12,91 kW	130 m^2	Thermal heating
2	13 909 kWh	7,32 kW	122 m^2	Electric heating
3	14 664 kWh	6,68 kW	167 m^2	Thermal heating
4	8 696 kWh	8,13 kW	67 m^2	Electric heating
5	15 549 kWh	7,23 kW	83 m^2	Electric heating

Case	*Yearly electricity consumption*	*Maximum power*	*Surface area*	*Heating system*
6	4 497 kWh	4,33 kW	120 m^2	District heating

The Table I presentation demonstrates that the study cases vary from each other, while the annual electricity consumption is between 4 497 and 21 554 kWh. However, to be able to study the solar energy production in each case, the basic information for the studied household cases has been utilized to obtain the information on what would be a suitable size for each individual solar energy system size. The results are presented in Table II, where the minimum size for the solar panel system was considered as 2 kW.

TABLE II. THE CAPACITY OF THE HOUSEHOLDS TO USE SOLAR ENERGY

Case	*Solar panel size*	*Solar energy production*	*Share used in households' own consumption*
1	3 kW	2 384 kWh	71 %
2	2 kW	1 617 kWh	72 %
3	3 kW	2 390 kWh	74 %
4	2 kW	1 620 kWh	48 %
5	4 kW	3 130 kWh	72 %
6	2 kW	1 594 kWh	45 %

Table II results list out the solar system sizes, the modelled solar energy production, as well as, the percentage of the amount of energy being utilized in the household itself for each study case. One should notice that the simulation for the cloudiness using random factor is the reason why same size systems have produced different amounts of energy. However, each of the cases have had solar system maximum load between 797–810 hours per year.

The results in Table II indicate that cases 1, 2, 3 and 5 would be able to use more than 70 per cent of the solar energy in their households, whereas cases 4 and 6 could only utilize less than 50 per cent. This ratio indicates that the cases 4 and 6 would not be able to utilize solar energy enough for it to be economically feasible for them [18].

Additionally, the economy of the solar system needed to be studied more in detail to see what the investment for each household case would be like. These results are stated in Table III, where due to Table II outcome cases 4 and 6 are excluded.

TABLE III. THE ECONOMY OF SINGLE HOUSEHOLDS PRODUCING AND USING SOLAR ENERGY

Case	*Annual solar energy production*	*The investment required*	*Economic yield during 1st year*	*Payback time (a)*
1	2 384 kWh	4 590 €	132 €	22 years
2	1 617 kWh	3 330 €	90 €	23 years
3	2 390 kWh	4 590 €	137 €	21 years
4	-	-	-	-
5	3 130 kWh	6 115 €	175 €	23 years
6	-	-	-	-

In Table III payback time, an assumption was made that the electricity price would increase by 4 per cent each year. Regardless, the payback times for each household case exceeded 20 years. The technical age for the panels is considered as 20 to 30 years [19]. Therefore, the investment is dependent on the guarantee and durability of the solar system.

The Table III results demonstrated that the total investment of the solar systems would be 18 625 euros, and the revenue from the first year would be total of 534 euros. Furthermore, the payback time for all the systems together would be 22 years. In case the solar panels would only function for the 20 years, the internal interest rate of the return would be -1 per cent. On the other hand, if the solar panels would produce energy for 30 years, the internal rate of return would be +3 per cent for the investment.

B. Households sharing solar energy as a community

The idea of the solar community would mean that the household cases in results section A would invest in one larger solar system together, where they would produce electricity together. This would also mean that their consumption would be combined into one. The study for this part considers two possibilities that the community could consider.

Firstly, the combined need for the solar panels, according to Table II and III results would be 12 kW (cases 1,2,3 and 5). In this case, the estimated investment price for the solar panels would be 16 200 euros. In total, the households with combined consumption would be able to utilize 81,7 per cents of the solar energy production. The revenue for the first year would be 579 euros, and the payback time for the investment would be 19 years. In case the panels would produce energy for 20 years, the internal rate of return would be +1 per cent. On the other hand, an operation time of 30 years would yield an internal interest rate of +4 per cents.

Secondly, the energy community could increase their solar panel size to 18 kW (cases 1 to 6), and still obtain a 70 per cent share of the energy utilized in the community. In this case, the investment for the solar system would be 23 976 euros. The payback time for the investment would be 20 years, and the first year of production would produce an income of 788 euros. In terms of internal interest rate, the 20 years of production would equal to +0 per cents. However, the 30 years of production would mean an internal rate of return of +4 per cent.

In case of energy community, the solar system with limited size would be more beneficial for the community, since it is guaranteed to yield some profit for the community regardless of the system production time.

IV. DISCUSSION

According to the results of this study, the energy communities in solar energy could be beneficial in several ways. The economic advantage of one larger system produced 13 per cent savings in the investment price of the solar energy system. The solar energy compensation in the energy usage was 8 per cent better than in individual household cases. Furthermore, the payback time for the investment was obtained as 3 years shorter. Additionally, the maintenance of one bigger unit could be assumed as more affordable. On contrast, the disadvantages of solar energy communities, are those of increased transmission losses.

Additionally, there are also technical obstacles in the use of solar energy, since solar energy production measuring versus consumption is still technically very versatile. The system profitability can depend on how the electricity network operator accounts for the solar system production, and how close to the real life the solar production and the consumption really connect. [20]

The study case presented in this paper also has limitations, that the real-life data without further analysis sets. The electricity consumption of the household cases during sunny seasons and daytimes have a significant bearing into the system size, investment price, as well as, to overall economy of the planned solar system. In this study, the data utilized was that of real-life households that have their unique consumption profile. However, it might be plausible to modify certain consumption peaks in case a household producing solar energy wanted to utilize the maximum amount of the produced solar electricity.

For instance, the majority of electrically heated households in Finland produce hot water using electric water boilers. Normally, the boilers are set to heat the water during the nights, since that way their consumption balances the day-time electricity consumption that is much more difficult to predict. In case a household had very little of day-time electricity consumption, the solar energy could easily be utilized in hot water production. This is just one example of energy intensive consumption, that is not totally fixed to the time of the day, when the system could be running. Therefore, the maximum amount of plausible consumption would require a more detailed study, where each household consumption profile would be studied more in detail.

V. CONCLUSION

The results of this study indicate that energy communities could very well be an answer to obtaining more solar energy production in Finland. The energy communities would be economically beneficial for the households connected to it, but they would also be beneficial for the electricity system providers, since they are easier to manage. There could also be business possibilities in providing solar energy services to individual households or other private sector representatives to obtain the needed renewable energy without having a system of one’s own.

The recommendation of this study is that the solar energy should be made more lucrative to all private sector representatives to rush the transition towards solar energy utilization in Finland. The private sector representatives are ready to make the transition, but the only benefits obtained from the government are those of domestic tax reductions related to the work when the system is being installed or maintained. The swift transition towards renewable energies would require more benefits for those willing to make the transition.

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