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The efficiency of grid-tied PV systems on small farms in Latvia

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Abstract: Photovoltaic (PV) systems are becoming more and more popular around the world, and Latvia is not an exception. This is mainly due to the increased efficiency and reduction in price of PV modules. However, Latvia still ranks below most European Union countries in the use of PV modules for electricity production. A significant problem for many farms and households in Latvia which use PV modules, is the lack of storage for the produced electricity. As a result, large amounts of electricity are sold for a relatively low price and while being bought from the main grid for a relatively high price. The aim of the study is to determine and compare the electricity consumption and PV systems producing electricity each month on the Jasmini Farm during 2020. The study shows that during the year, only 25.4% of all the electricity used on the Jasmini Farm was from PV modules, but the rest of the electricity was bought from the main grid. Furthermore, from all the electricity which PV modules produced in 2020, only 29.5% was used on the farm, while the rest was sold to the main grid.

Keywords: renewable energy, solar power, PV module, grid-tied system, electricity

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Introduction

Solar energy is the most abundant and cleanest renewable energy source. Solar heating and photovoltaics (PV) are the two most common technologies using solar energy. PV systems, especially, are becoming more and more popular around the world. This is mainly because of the reduction in price and the increased efficiency of PV modules (*Solar energy*).

Producing electricity from PV modules is a relatively new invention, but the concept has grown rapidly, especially in the last 10 years. In 2010, solar energy shared only 3.4% of the total renewable electricity capacity around the world, but today, according to the latest estimates, this number has grown to 23.09% (Fig. 1) (*Renewable capacity statistics*, 2020).

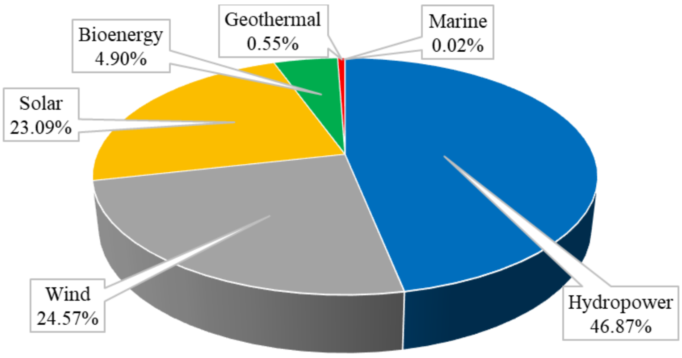

Fig. 1. Renewable electricity capacity around the world (*Renewable capacity statistics*, 2020)

Figure 1 shows that almost half of the world's renewable electricity capacity comes from hydropower, about 20% from wind and solar energy, almost 5% from bioenergy and less than 1% from geothermal and marine energy. This shows a diversity found around the world that is not present in Latvia (Fig. 2).

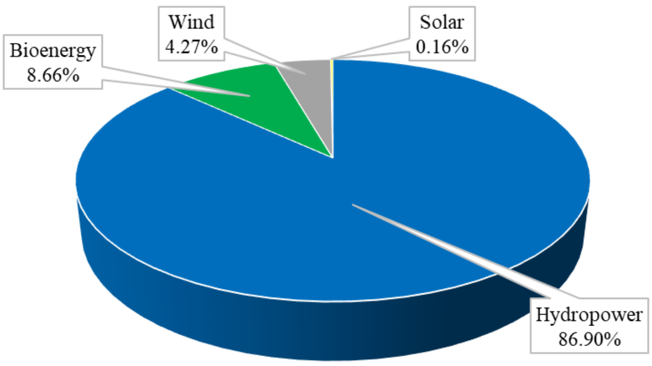

Fig. 2. Renewable electricity capacity in Latvia (*Electrical capacity from renewables*)

Figure 2 shows that in Latvia almost all of the country's renewable electricity capacity is produced from hydropower. The majority coming from the three largest hydroelectric power plants in Latvia. Less than 10% comes from bioenergy, less than 5% is from wind energy, and solar energy produces only 0.16% (*Electrical capacity from renewables*).

According to the Central Statistical Bureau of Latvia, the total electrical capacity coming from solar energy in Latvia in 2019 was only 3 MW (*Electrical capacity from renewables*), but in neighboring countries like Lithuania and Estonia this number is much higher. In Lithuania the total electrical capacity from solar energy is 103 MW and in Estonia 107 MW (*Renewable capacity statistics*, 2020). This shows that the potential of solar energy in Latvia is drastically underused, and explains why Latvia ranks last among the Baltic States and one of the last in the European Union in terms of using solar energy for electricity production. However, despite the relatively low electrical capacity from solar energy in Latvia, PV modules are becoming more and more popular in many households and farms.

As in many other industries, PV technology in agriculture is becoming more and more important because of the increasing dependence on energy. It has been concluded that PV decision-making is driven by economic and environmental considerations and that, although ethical considerations are relatively strong among farmers, they cannot be used as predictors in the decision-making process (Brudermann et al., 2013). Photovoltaic agriculture, a combination of photovoltaic energy production and agricultural activities, is a natural response to the supply of green and sustainable electricity to agriculture. It offers a new opportunity for the photovoltaic industry, but more theoretical and practical research is needed to optimize the combination of photovoltaic energy production and agriculture activities (Xue, 2017).

An important issue is the use of the solar energy system's environment for agricultural purposes. Situations, where the PV modules are located on the roof of a greenhouse, are especially well studied in (Kadowaki et al., 2012). The study, in which PV modules were installed on half of a greenhouse's roof area, showed that solar radiation in the greenhouse decreased by an average of 64% per year (Cossu et al., 2014). In addition, it is argued that by selecting different types of PV modules, it is possible to obtain a light spectrum distribution that is ideal for plant growth (Kuo et al., 2012).

A study in Latvia showed that technological advances and the economic situation in the solar energy sector has achieved cases where PV systems would achieve a pay back in 10 to 16 years (Rozentale et al., 2018). In another study in Latvia, it was concluded that PV module overheating causes power losses. Results showed that a PV module overheating to over 50°C can cause power losses over 12 $W \cdot m^{-2}$ (Stanka et al., 2020). A significant problem for many farms and households in Latvia, which uses PV modules, is the lack of storage for the produced electricity. As a result, large amounts of electricity are sold for a relatively low price and large amounts of electricity are bought from the main grid for a relatively high price.

The aim of the study is to determine and compare electricity consumption and electricity produced by PV systems each month on the Jasmini Farm in 2020.

1. Materials and methods

Research to determine the efficiency of PV modules took place on the Jasmini, Farm which is located in the eastern part of Latvia (geographical 56°42'53.46" N latitude and 27°3'0.68" E longitude). The farm is mainly specialised in field crop growing on an area of approximately 400 ha. As with many farms in Latvia, the biggest electricity consumption on the farm is in summer. On February 2019, in order to save money on electricity, a total of 22 polycrystalline RECOM Amur Leopard 270 W PV modules were installed on the roof of an agriculture machinery shed (Fig. 3).

Fig. 3. PV modules located on the Jasmini Farm (*author's own photography*)

The total area of the PV modules is 35.79 m^2, and the total nominal power of the PV system is 5.94 kW. The PV modules face south-west with a solar azimuth of 203° and a tilt angle of 30°. Considering the geographical location, the solar azimuth, the tilt angle of the PV modules and the nominal power of the power plant, it was calculated that on average this PV system is capable of generating 5564 kWh of electricity per year. In the last 5 years, the annual electricity consumption on the Jasmini Farm is approximately 5000 to 7000 kWh of electricity.

The PV system is grid-tied. This means that the electricity produced from the PV modules, which is not used at that moment, is sold through the electricity meter to the main grid. Unfortunately, the farm does not have solar batteries to store the produced electricity. As a result, large amounts of electricity are sold for a relatively low price to the main grid. Furthermore, from sunset to sunrise and in bad weather conditions, when the PV modules are not producing enough electricity, large amounts of electricity are bought from the main grid at a relatively high price.

This is a significant problem in Latvia and in the rest of the world for many households, which uses PV modules. In this study, the electricity consumption and electricity produced by the PV systems each month on the Jasmini Farm in 2020 was determined and compared.

2. Results and discussion

In 2020, the electricity consumption on the Jasmini Farm was 6609.60 kWh, PV modules produced 5692.02 kWh of electricity, but from the main grid 4930.55 kWh of electricity was bought. Detailed information about the consumed, produced and bought electricity on the Jasmini Farm in each month of 2020 is shown in Table 1.

Table 1. Consumed, produced and bought electricity on the Jasmini Farm in 2020 (*own research*)

Month	Electricity, kWh		
	Consumed	Produced	Bought
January	469.65	71.41	437.65
February	440.62	203.02	367.79
March	552.50	479.04	385.19
April	564.66	649.12	358.16
May	540.91	854.11	319.83
June	665.45	944.01	401.21
July	666.24	845.21	436.57
August	682.45	764.03	460.41
September	555.58	560.14	405.14
October	430.41	196.02	350.48
November	511.02	69.87	471.93
December	560.10	56.04	536.19

The data in Table 1 shows that the monthly consumption of electricity was between 430.41 to 666.24 kWh, produced electricity was between 56.04 to 944.01 kWh and the bought electricity was between 319.83 to 536.19 kWh. In addition, it is clear that the largest electricity consumption and production is in the summer.

The annual data shows that the PV system is capable of producing 86.12% of the total electricity consumption on the farm. However, considering that the produced electricity from the PV modules, which is not used at the exact moment, is sold through the electricity meter to the main grid, the data shows that the electricity is mainly bought from the main grid. Distribution of the electricity consumption on the farm Jasmini in 2020 is shown in Figure 4.

The data in Figure 4 shows that the highest amount of electricity from the PV modules was consumed in June at 40.89%, but the least electricity consumption from the PV modules was in December at only 4.28%. The annual data shows that only 25.40% of all the electricity consumption on the farm was from PV modules, but the rest of the electricity was bought from the main grid. In addition, the rest of the PV system's produced electricity was sold to the main grid. The distribution of electricity produced by the PV modules is shown in Figure 5.

The data in Figure 5 shows that the monthly consumption of electricity produced by the PV modules was from 25.90 to 55.77%, but annually only 29.50%. The rest of the electricity was sold (fed into) to the main grid.

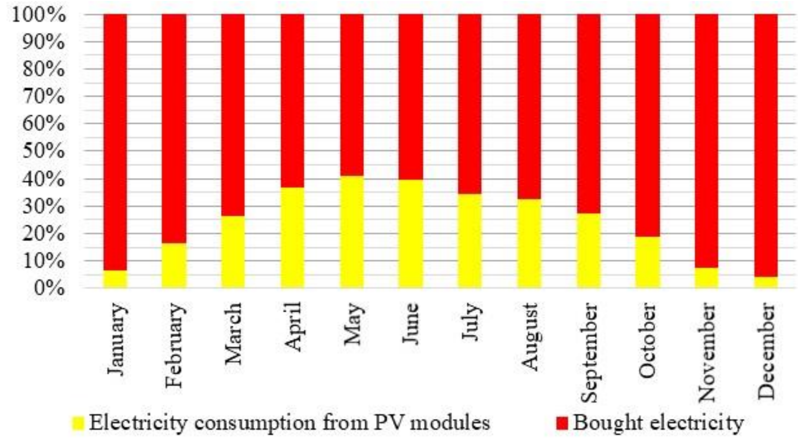

Fig. 4. Distribution of the electricity consumption on the Jasmini Farm in 2020 (*own research*)

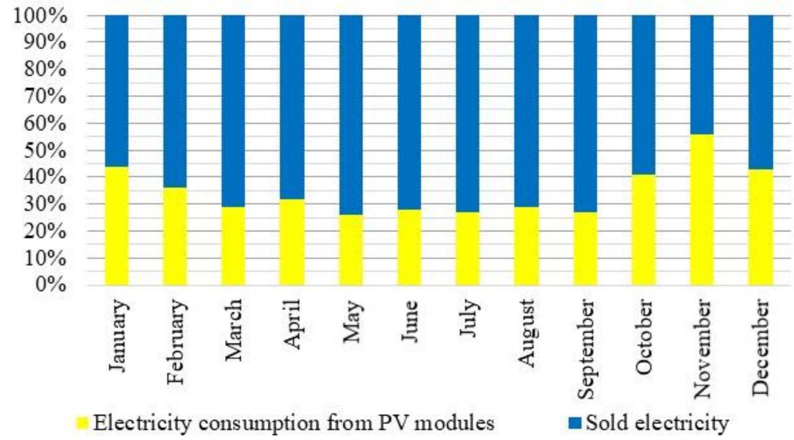

Fig. 5. Distribution of electricity produced by the PV system on the Jasmini Farm in 2020 (*own research*)

Considering all the aforementioned data, it is clear that most of the electricity used is bought from the main grid, but the electricity produced by the PV modules is mostly sold to the main grid. However, in another study conducted in the western part of Latvia in a household with a PV system capable of producing about 243 kWh/month, the results showed that, in average, 60 kWh/month are fed into the grid, and around 110 kWh/month are bought from the main grid (Rozentale et al., 2018).

Solar batteries can significantly reduce the amount of sold electricity in months where the amount of produced electricity is higher than the electricity consumption. To better illustrate this, Figure 6 shows the electricity produced by the PV modules, the electricity consumption from the PV modules and the electricity bought from the main grid in each month.

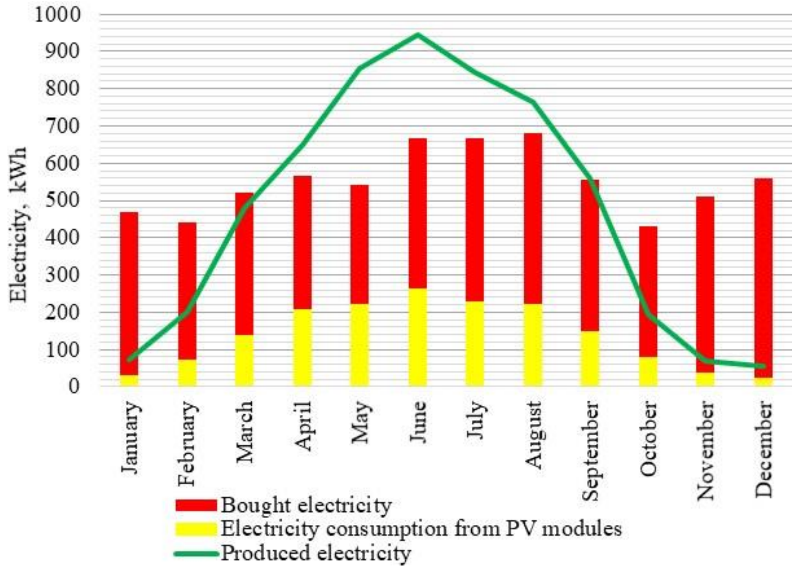

Fig. 6. Bought, consumed and PV systems produced electricity on the Jasmini Farm in 2020 (*own research*)

The data in Figure 6 shows that, theoretically, by using solar batteries for electricity storage, it is possible to use only electricity produced by the PV system in April, May, June, July, August and September. In other words, for half of the year, it is possible to live without buying any electricity from the main grid. However, this is only theoretical, as there can be moments when PV modules cannot produce enough electricity due to several consecutive days of bad weather. Therefore, in this case, solar batteries would not help. In addition, in a study in Latvia where 15 households with PV systems were analyzed, in all 15 households the average monthly consumption of electricity was higher than the produced electricity from PV modules. Therefore, in these households it is not possible to rely only on the PV system. Electricity from the main grid is needed (Rozentale et al., 2018).

For more precise results, it is necessary to study the consumption and production of electricity on the farm each day as electricity consumption and production can vary widely throughout the day during different periods. In addition, it would be necessary to evaluate data from more than one season and in different geographical locations across Latvia.

Conclusions

PV systems are becoming more and more popular around the world, and Latvia is not an exception. This is mainly because of the reduction in price and the increased efficiency of PV modules. However, Latvia still ranks as one of the lowest countries in the European Union in terms of the use of PV modules for electricity production.

A significant problem for many farms and households in Latvia that use PV modules, is the lack of storage for the produced electricity. As a result, large amounts of electricity are sold for a relatively low price to the main grid while electricity is bought from the main grid for relatively high prices. This is confirmed by the Jasmini Farm study.

The study showed that in 2020 only 25.4% of all the electricity consumption on the farm was from PV modules, and the rest of electricity was bought from the main grid. Furthermore, from all the electricity that PV modules produce, only 29.5% was used by the farm, and the rest was sold to the main grid.

Solar batteries could improve this situation as they could store electricity for later use. However, the amount of storage is limited. Therefore, it would be necessary to study the consumption and production of electricity on the farm during each day and at each moment as electricity consumption and production can vary widely throughout the day.

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