PROJECT PEGASUS

3.4.6
FINAL REPORT ON THE COST BENEFIT ANALYSIS AT THE RUŠE SPORTS PARK AREA

Maribor, October 2019

NAME

FINAL COST BENEFIT ANALYSIS REPORT FOR RUŠE SPORTS PARK AREA

AUTHOR:

ENERGETSKA AGENCIJA ZA PODRAVJE- zavod za trajnostno rabo energije

Smetanova ulica 31

2000 Maribor

Tel: (+386) 02 234 23 60

Fax: (+386) 02 234 23 61

web: www.energap.si

Project co-financed by the European Regional Development Fund

Content

Pictures

Tables

1. Introduction

1.1. Purpose and objectives of the project

The basic idea of the pilot project in Ruše as part of the European project PEGASUS is to analyze the feasibility of a self-sufficient micro-network of several buildings in order to improve the efficient use of renewable energy sources and the quality of electricity supply through the established micro-network.

Based on a group of facilities that could be a self-sufficient network, a system for measurement of electricity produced and consumed was established. On the basis of the obtained data of the measurements that take place from March 2018 until today, we will simulate the operation of the micro network and assess the quality of the obtained measurements of the solar panels.

The basis of the net metering system is annual calculation at the same electricity supply point between energy produced in the solar power plant and the energy consumed. This means that the micro network with the included facilities is connected to the public distribution network, whereby it acts as an energy stabilization device. If we want to see the technology of diffused electricity generation in the future in place, it is necessary to implement micro networks in the existing network. The basic goals of modern energy are namely reliable electricity supply, use of renewable resources, environmental protection and, above all, the efficiency of the system.

The basic concept, which will be presented below, is the micro network model, based on which we will explore several possible variants of solutions from storing surpluses of electricity through battery systems to the inclusion of a small cogeneration unit that would also cover the heat demand in the facility.

All possible variants of the reconstruction of the heating system will be economically and technically evaluated and give an independent expert assessment for further measures in the field of lowering the consumption and energy costs. Implementation of the micro network would definitely bring about significantly reduced primary energy consumption to an estimated 30% and increase the use of renewable energy sources to 25%. The costs of supply (heat, electricity) should be reduced or equal, but they will need to be calculated.

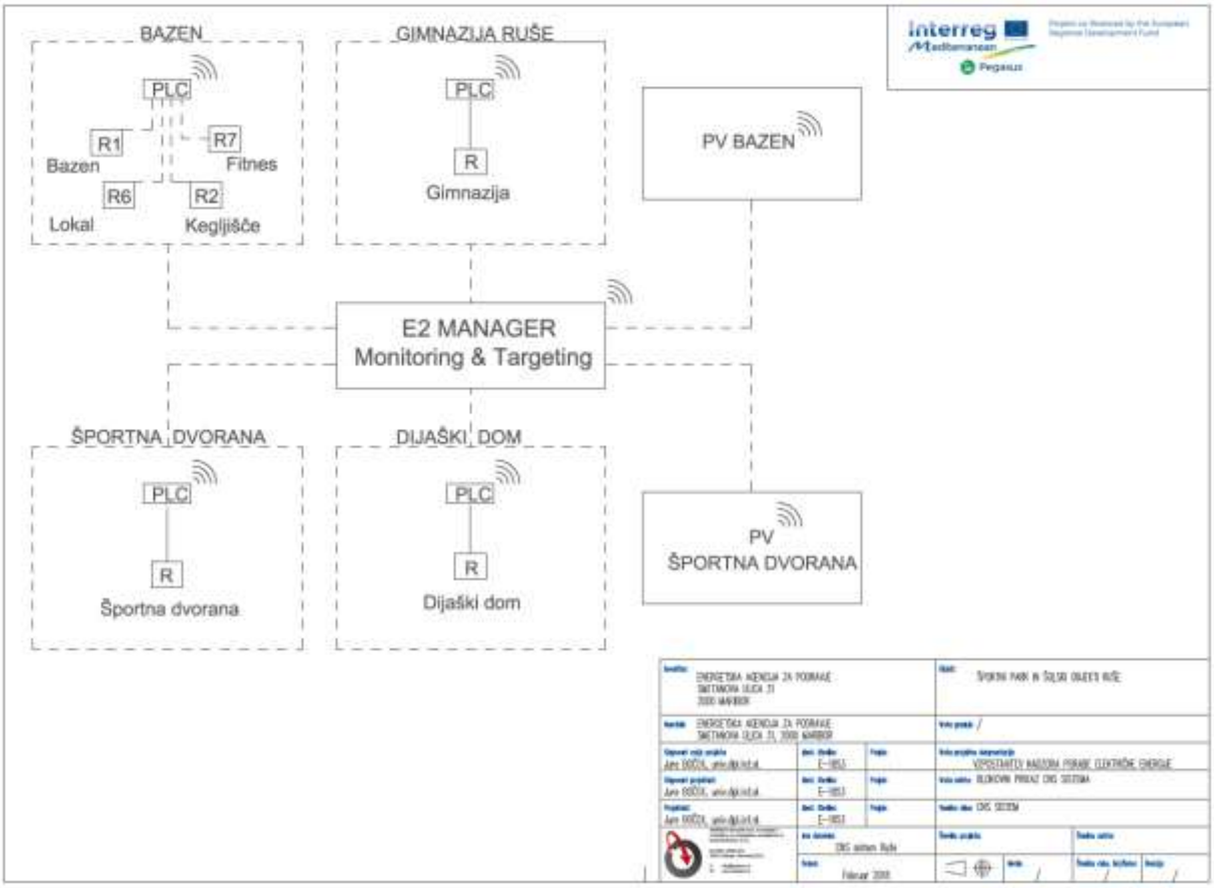
The results of the project will assist planners and users of micro-networks in Slovenia for similar installations that require a constant need for electric and thermal energy with the possibility of using renewable energy sources.

Project co-financed by the European Regional Development Fund

1.2. Description of the pilot project of the micro network in Ruše

A complex of four buildings was selected as a potential micro-network of several buildings; that is, the Ruše Sports Park (which includes a swimming pool, fitness room, restaurant and bowling alley), Ruše Sports Hall, Gymnasium and Secondary School of Ruše and the Ruše Dormitory House. The decision was simple because at two of the four buildings, more precisely on the roofs of the Ruše Sports Park and the Ruše Sports Hall, solar collectors have already been installed, and already we have a large production potential of renewable energy.

The picture below shows the scheme for setting up monitoring of consumption measurement with individual buildings that represent the micro network and from which we collect energy data and are entered and analyzed in the energy bookkeeping of E2 Manager software.



Picture 1: Scheme of the micro network

Due to already installed solar modules on the roofs of the Sports Hall and the Ruše Sports Park, a separate measuring system was established, which includes the existing photovoltaic and both buildings. The measuring system measures electricity production on four separate electricity output points to which solar panels are divided with a total power of 99.77 kW and energy consumption at both facilities.

The meters at the Ruše Gymnasium and the Ruše Dormitory House are under construction, so we will focus on the previously mentioned buildings.

2. Energy consumption movement in the buildings

Control of energy consumption in the Ruše Sports Park is monitored through the E2 Manager software. Based on the analysis of energy bookkeeping, it has been found that the potential for energy savings is existent.

The building of the Ruše Sports Hall has a conditioned area of the building Ak = 2.197 m^2. The annual electricity consumption in 2017 was 55,687 kWh. Consumption in 2017 slightly increased to 58.057 kWh. The heat energy collection for heating has a Sports Hall arranged in conjunction with the Gymnasium Ruše.

The building of the Ruše Sports Park has a conditioned area of Ak = 2.868 m^2. In 2017, 421,817 kWh of electricity were used, and the required heat for heating was 1,2 GWh.

2.1. Electricity and thermal energy costs at the site in 2017

In 2017, the total consumption of electricity in both facilities amounted to 0.4775 GWh of electricity or 0.4775 GWh or 1.73 TJ. The total cost of electricity was € 57,134.

The total required heat in 2017 for the heating of the Ruše Sports Park facility was 1,204,414 kWh of heat energy. The cost of natural gas for heating was € 67,617. A wood biomass boiler in the boiler room of the Ruše Gymnasium provides a heat for heating the Ruše Sports Hall.

Sport Hall Ruše	***Consumption***	***unit***	***TJ***	***cost in €***
Electric energy	55.687	kWh	0,21	8953

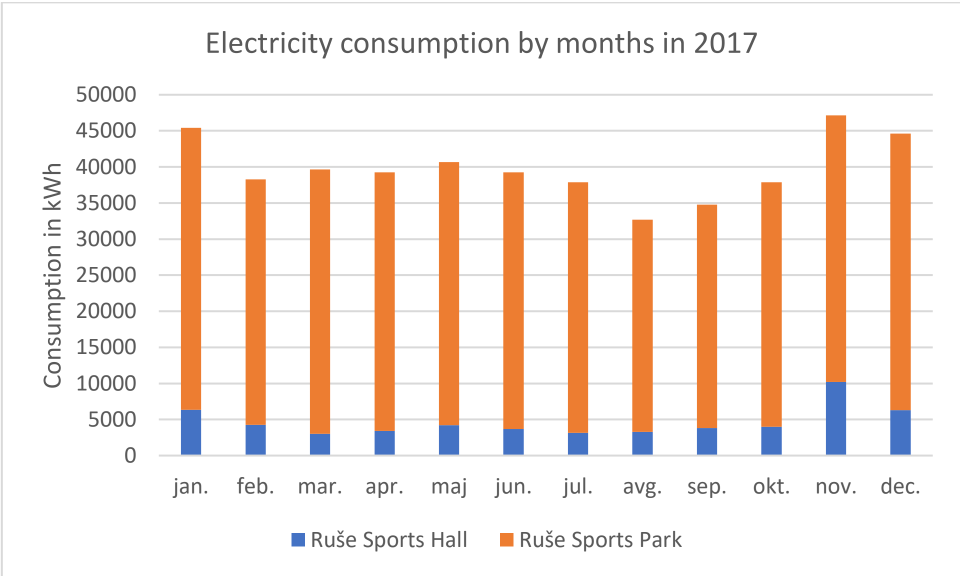
Table 1: Consumption and costs for the Ruše Sports Hall

Sports Park Ruše	***Consumption***	***unit***	***TJ***	***cost in €***
Electric energy	421817	kWh	1,52	48180
Natural gas	1205414	kWh	4,33	67617

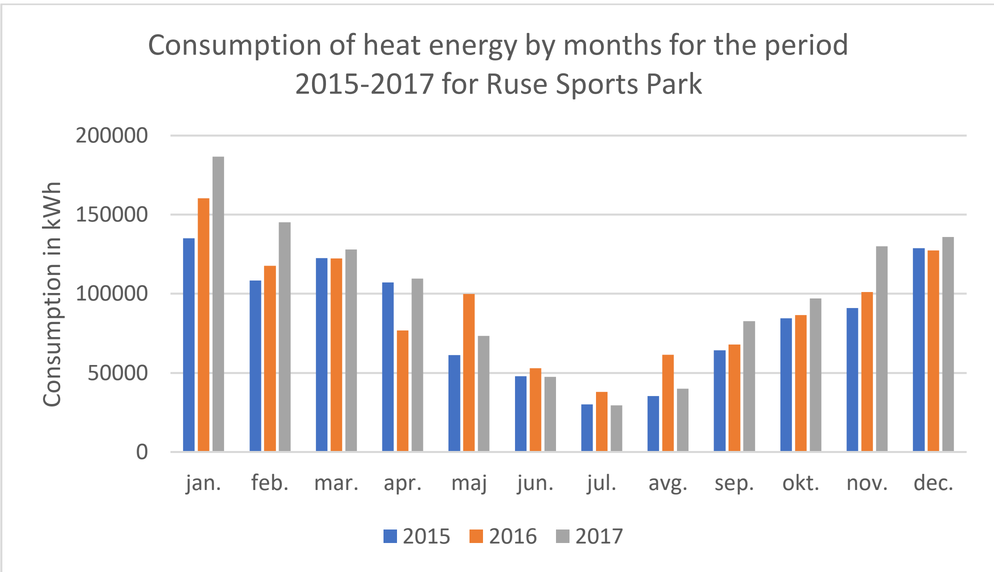
Table 2: Consumption and cost for the Ruše Sport Park

Based on the basic data on the annual consumption of heat for heating, depending on the total area of heated rooms, 2,868 m2, we calculate the energy number of the building, which represents the quotient of numbers (kWh/m2 year). For the Ruše Sports Park, the heat consumption for heating the pools, the buildings and the sanitary water is taken into account in the consumption of heat energy. The total specific heat consumption in 2017 was 420 kWh/m2.

From the graphs below, it can be seen that Swimming Pool Ruše with an annual consumption of thermal energy in the range of 1.2 GWh and consumption of electricity in the range of 0.42 GWh is among the more energy-intensive buildings.



Graph 1: Electricity consumption at the Sports Park and the Ruše Sports Hall



Graph 2: Consumption of thermal energy by months for the period 2015-2017 for Pool Ruše

As shown in the graphs, the consumption of electricity and heat in the winter months is increasing. The consumption of electricity is greater due to the operation of the pumps in the boiler room and the prolonged lighting time. Maximum electricity consumption is in January and December and ranges between 44 and 46 MWh.

Despite the relatively new facility, the opening of the Ruše Sports Park was in 2007 and some additional energy recovery measures during years, the costs of energy were not reduced.

In the facility, in the past, a cogeneration for the production of heat and electricity with 150 kW of rated electrical power and 220 kW of rated thermal power has already been installed, but due to the oversized system it has only been operating for several months. On the roof of the building, a solar power plant in the size of 2x50kW of installed power was installed privately.

3. Operational monitoring of performance of the solar power plant

Measurements and monitoring of the operation of the solar power plant take place on the premises of the Ruše Sports Park and the Ruše Sports Hall from 9.3.2018 to the present day. From the official records of Borzen, the operator of the electricity market, we can learn the exact installed power of the photovoltaic power plant. The Ruše Sports Park is 49.86 kW and the Ruše Sports Hall is 49.91 kW. The total installed power is 99.77 kW. Electricity is currently sold in the network at a fully subsidized price.

Name and address of the installed pnat	Name and address of the owner / operator of the device	Network operator	Type of production	Technology	Power [kW]
Photovoltaic power plant Ruše- roof of the pool - Šolska ulica 17, 2342 Ruše	STAR SOLAR, druga proizvodnja električne energije d.o.o. - Delpinova ulica 18, 5000 Nova Gorica	Elektro Maribor, d.d. - Vetrinjska ulica 2, 2000 Maribor	RES	Solar photovoltaics	**49,86**
Photovoltaic Power Plant Ruše Sports Hall – Šolska ulica 16a, 2342 Ruše	STAR SOLAR, druga proizvodnja električne energije d.o.o. - Delpinova ulica 18, 5000 Nova Gorica	Elektro Maribor, d.d. - Vetrinjska ulica 2, 2000 Maribor	RES	Solar photovoltaics	**49,91**

Table 3: Information about the owner and operator of a photovoltaic power plant

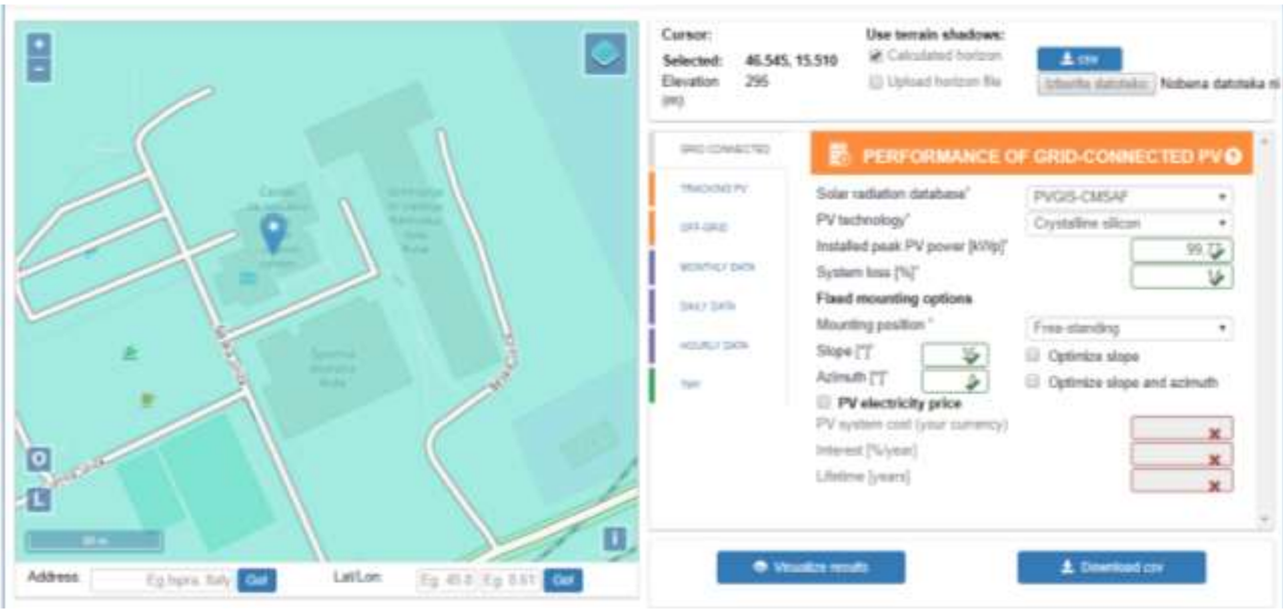
The solar power plant is free standing installed on the roof and achieves the maximum possible recovery due to its optimal southward orientation of 35 degrees.

Interreg Mediterranean Pegasus
Project co-financed by the European Regional Development Fund

3.1. Calculation of the efficiency of the solar power plant

For a simple calculation and assessment of the amount of electricity produced by the solar power plant, we can use the tool offered by the PVGIS geographic information system covering Europe, Africa and South-West Asia.

When the web page opens, we first mark the exact position of the building in the left window, and determine the position of the solar modules on the right side, the installed size of the solar power plant, determine the losses of the solar power plant (cloud, dust, cable length) about 5% and the type of photovoltaic panels.

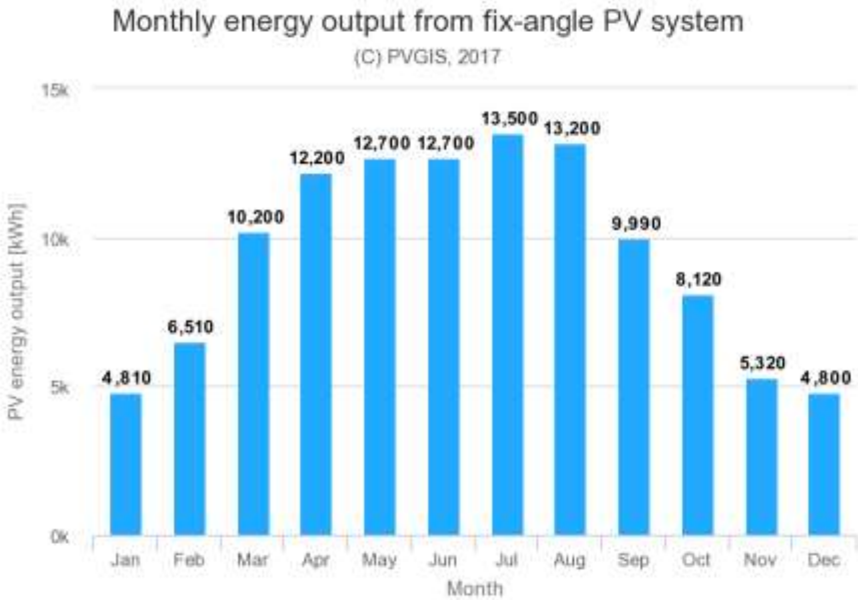


Picture 2: Display of the control panel of the interactive tool for calculating the capacity of the operation of a photovoltaic power plant

Provided inputs:	
Location [Lat/Lon]:	46.545, 15.510
Horizon:	Calculated
Database used:	PVGIS-CMSAF
PV technology:	Crystalline silicon
PV installed [kWp]:	99.77
System loss [%]:	14

Simulation outputs:	
Slope angle [°]:	35
Azimuth angle [°]:	0
Yearly PV energy production [kWh]:	114000
Yearly in-plane irradiation [kWh/m^2]:	1420
Year to year variability [kWh]:	7600.00
Changes in output due to:	
Angle of incidence [%]:	-3
Spectral effects [%]:	1.5
Temperature and low irradiance [%]:	-5.2
Total loss [%]:	-19.7

Picture 3: Calculated simulation results



Picture 4: Results of the maximum possible yields of electricity produced

Based on the results we can conclude that at the annual level, the quantity of electricity produced for a solar power plant with a nominal power of 99.77 kW would amount to 114.050 kWh of electricity. Altogether, for the period of installed meters, after the simulation between March and November, 97.930 kWh of electricity would be produced, representing as much as 86% of all production at the annual level.

3.2. Measuring system for controlling the production and consumption of energy

The measuring system established at the Ruše Sports Park facility consists of 8 main components:

1) Industrial power supply Omron S8VK-G06024, with output power 60W, 24V output voltage and during 2.5A.

2) The Omron CP1L-EM30DR-D programmable logic controller has 18 DC (VDC) inputs and 12 relay outputs. The operating voltage of the inputs and outputs (I / O) is 24V.

3) Programmable logic controller and converter (C1PW-CIF11, CP1 RS 422/485).

4) 5-Port Internet Distributor.

5) 3G router.

6) Intelligent meter 3f KM50-E1-FLK for monitoring the generated and consumed electricity, current and voltage, reactive power, phase shift of reactive power, power factor and frequency.

7) Omron KM20-CTF-200A Transformer Transformer.

8) KM20-CTF-50A gauge transformer.

The meters are interconnected as shown in figure 5 below.

Picture 5: Connection of the measuring equipment into the monitoring system

The basic idea of the measuring system was that it would carry out measurements at intervals of 15 to 5 minutes. Depending on the composite system, measurements can be exported in the form of 5 minute intervals for two days, hourly data for 8 days, daily data for the month and monthly data for one year.

The aim is to obtain the exact electricity production profile from the graphs and compare it with the combined usage of electricity of all consumers connected to the measuring system. On the basis of the comparisons, we would produce a pattern that would serve us as a representative sample.

Figure 6 shows the control panel for the meters.

Picture 6: Insights into the dashboard measuring system

From the control panel, you can view the data between the different time periods and select a different coverage interval (daily, hour, 15 minutes, monthly, yearly). Insights are possible in various parameters (such as power, consumption, etc.) on four separate photovoltaic panel production on both buildings.

It is clear from the picture that the graph line is uneven due to insufficient data. It can be concluded that there were problems with the installed system and the data obtained. Internet crashes occurred and due to this graph is not displayed correctly. In two points, the graph line is markedly negative. On Tuesday, 5.6 and Sunday 1.7, a major downturn had to occur.

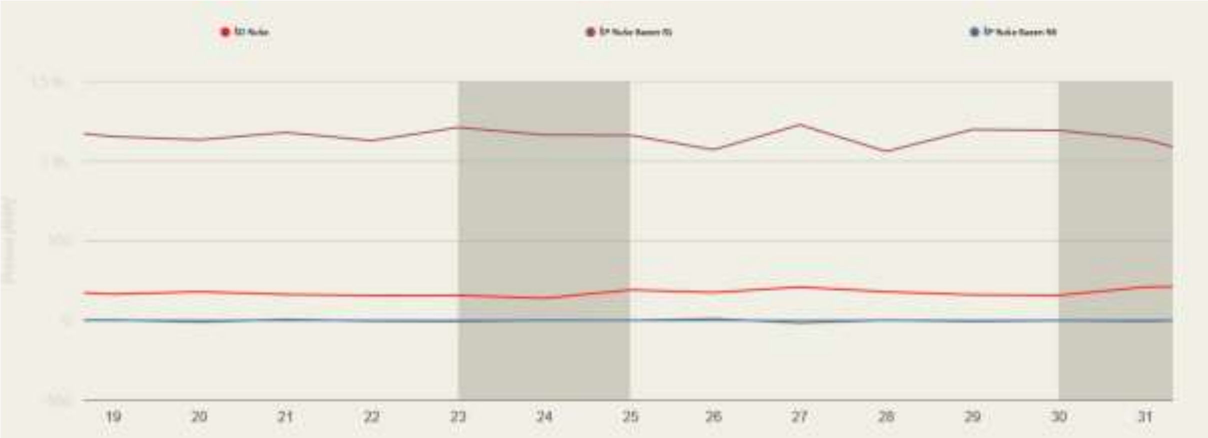
On the right side of the graph line, the amount of read shown measurements is inconsistent. It is likely that a measurement system failure has occurred.

It should be noted that good quality measuring equipment of a reliable subcontractor with good service capabilities is essential for good measurement.

3.3. Analysis of the obtained data of the measuring system

Among all the data, it was necessary to find a week of consistent measurements that would serve us as a representative sample.

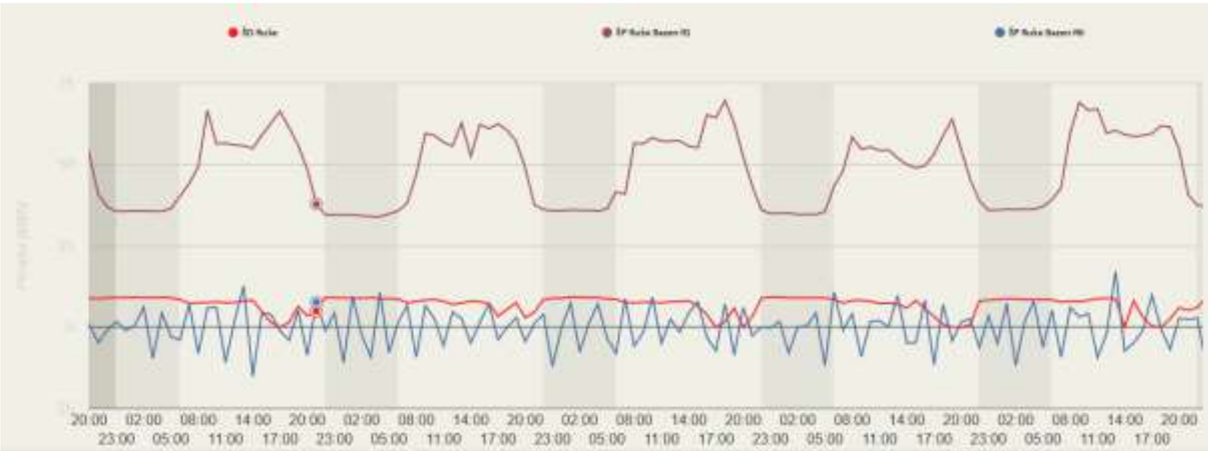
Project co-financed by the European Regional Development Fund



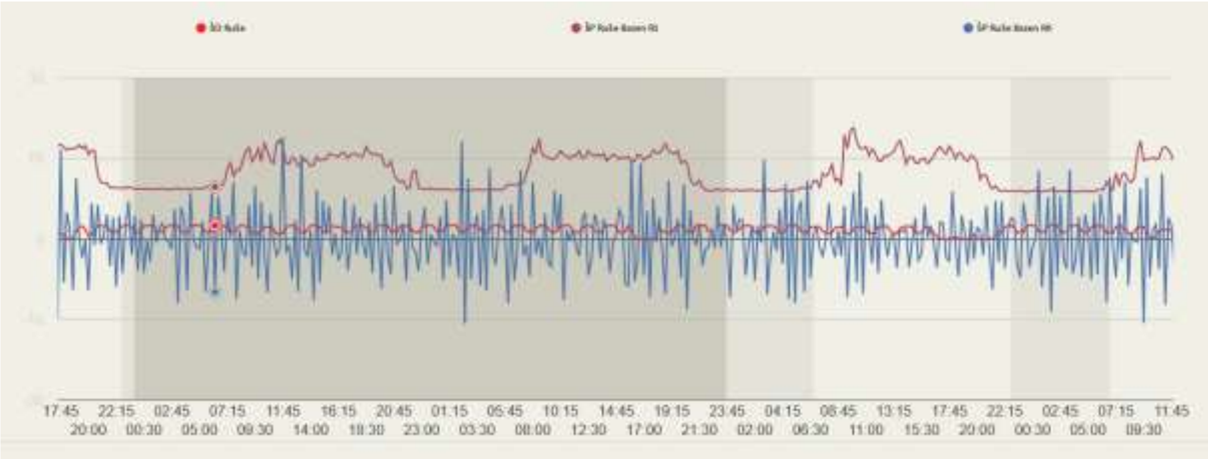
Graph 3: Weekly sample with daily use of meters

The blue and violet lines show the daily consumption of the two meters at the Ruše Sports Park facility, while the red line shows the consumption of the meter in the Ruše Sports Hall.

If we look at the graph below with an hour and 15 minutes intervals of power consumption, we can see a pattern that can be used in our everyday analysis of the micro network.



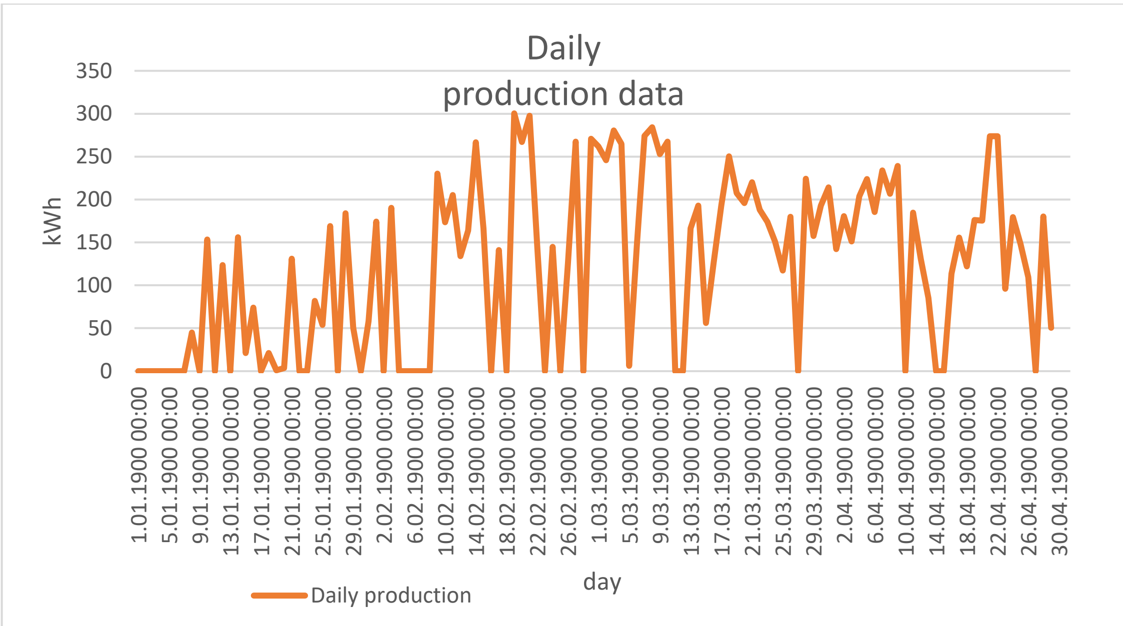
Graph 4: Representative weekly pattern with hourly power consumption



Graph 5: Representative daily pattern with 15 minutes interval of power consumption

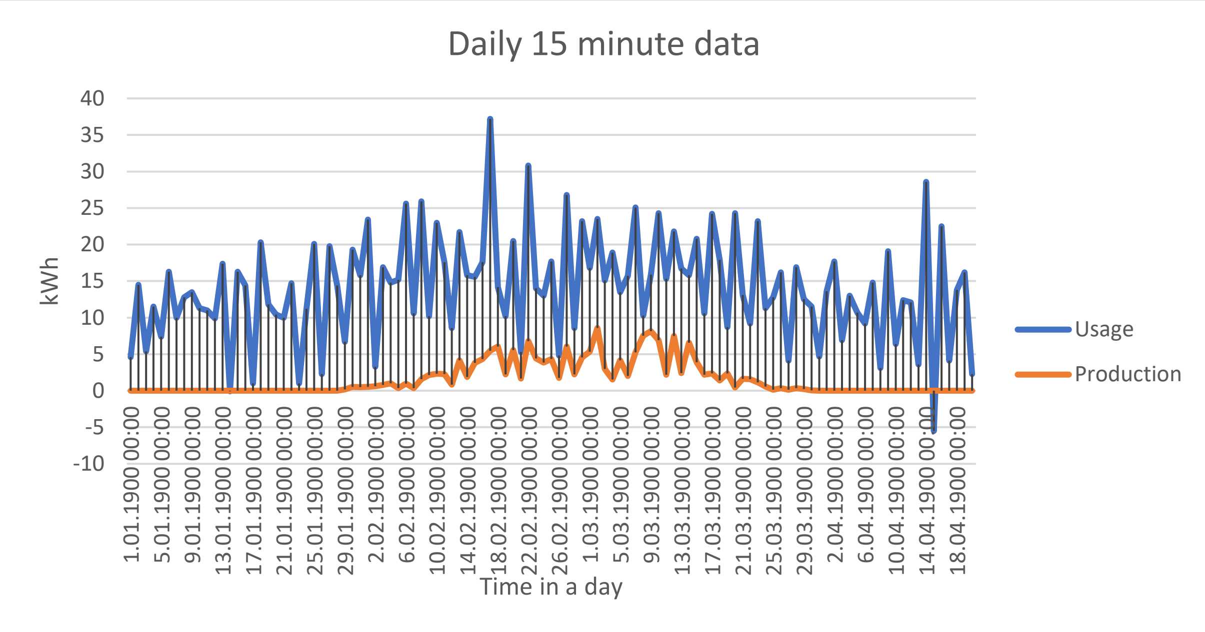
On the basis of the graph of the daily production of electricity, photovoltaic panels on the observed week, we notice that the data due to changes in the radiation of the sun during the day are quite dynamic.

It was also necessary to look at the graph of the maximum daily output of photovoltaic panels in order to determine the daily coverage with the renewable resources that the micro network will have.



Graph 6: Graph of electricity produced on 3.3.2018

For further analysis, it was necessary to analyze a sample of the average day of production. On the basis of the data, the production of solar power plant on 3.3.2018 was 174 kWh of electricity.



Graph 7: Graph of daily consumption and production of electricity on 3.3.2018

For the best picture of the performed measurements, we selected the most sunny month of the year after the simulation. After the simulation, in July, the production of electricity is 13,500 kWh, which on average amounts to 435 kWh of daily produced electricity.

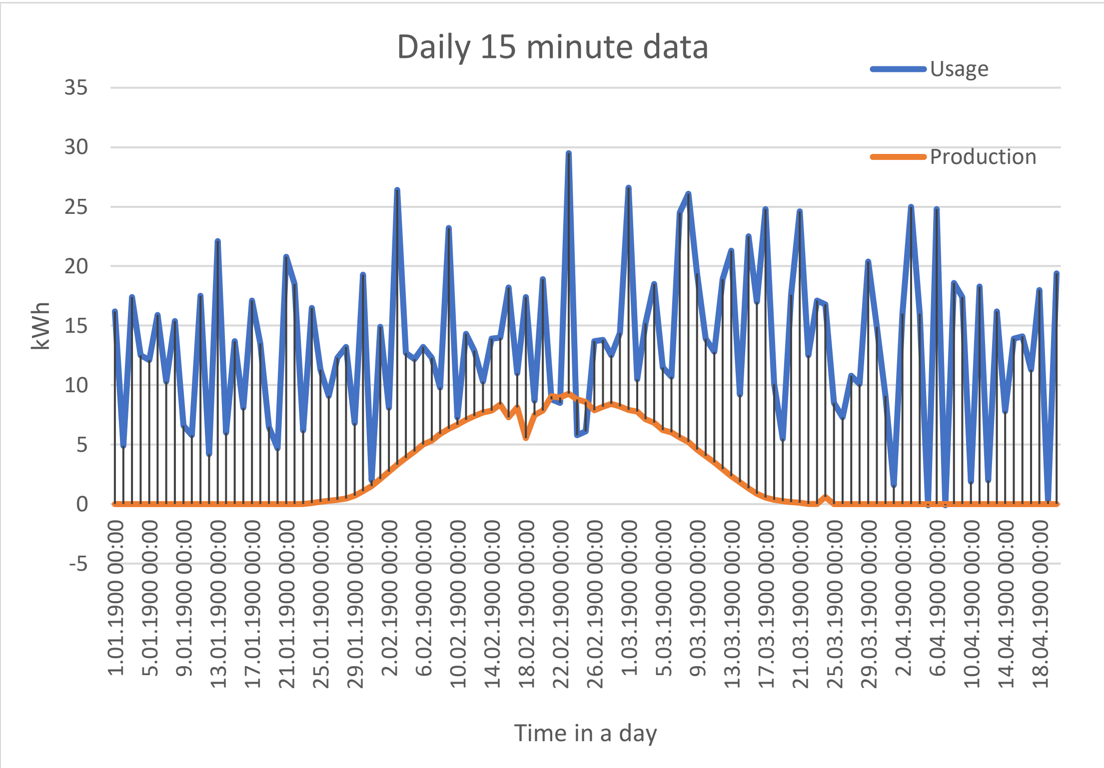
Time	production (SE panel1) [kWh]	production (SE panel2) [kWh]	production (SE panel3) [kWh]	production (SE panel4) [kWh]	Together
1.07.2018	-76.981	-96.560	-68.693	-76.483	/
2.07.2018	51.629	23.334	62.243	24.788	161.994
3.07.2018	55.119	54.521	54.597	45.339	209.576
4.07.2018	/	/	/	/	/
5.07.2018	69.232	68.539	68.769	57.236	263.776
6.07.2018	/	/	/	/	/
7.07.2018	/	/	/	/	/
8.07.2018	/	/	/	/	/
9.07.2018	11.995	12.062	12.110	9.954	46.121
10.07.2018	43.058	17.932	53.882	21.767	136.639
11.07.2018	20.508	8.783	24.004	8.784	62.079
12.07.2018	62.973	62.714	62.822	52.168	240.677
13.07.2018	45.779	20.935	54.574	21.746	143.034
14.07.2018	56.357	24.377	69.889	28.503	179.126
15.07.2018	44.514	44.293	44.550	36.902	170.259

16.07.2018	54.228	53.691	53.919	44.801	206.639
17.07.2018	57.400	24.741	70.841	28.646	181.628
18.07.2018	/	/	/	/	/
19.07.2018	0	0	0	0	/
20.07.2018	51.945	22.112	64.744	26.170	164.971
21.07.2018	45.259	19.054	56.554	22.799	143.666
22.07.2018	34.803	14.987	42.515	16.769	109.074
23.07.2018	14.087	5.936	16.428	5.656	42.107
24.07.2018	61.984	61.710	62.043	51.553	237.290
25.07.2018	60.422	59.840	59.996	49.898	230.156
26.07.2018	/	/	/	/	/
27.07.2018	/	/	/	/	/
28.07.2018	/	/	/	/	/
29.07.2018	0	0	0	0	/
30.07.2018	/	/	/	/	/
31.07.2018	72.946	72.438	72.476	60.331	278.191

Table 4: Energy production on a measuring system installed on the building

The measurements were in one case negative, in nine cases the measurements were not recorded and in two cases the recorded measurements were equal to zero, despite two sunny days.

The highest production was on 31 July 2017, ie 278 kWh of electricity.



Graph 8: Results of consumption and production of electricity on 31.7.2018

As shown in the graphs and analyzes, the production capacity of the solar power plant is lower than the consumption. The analysis of 31.7.2018, however, shows that production in a short interval of the day is greater than consumption. This means that in such a case, with an additional 30 kW energy storage, it would be possible to save excess energy and at the same time during the day evenly reduce the need for current excess power consumption (peak shaving) and thus reduce the cost of electricity.

According to the analyzed data, the currently installed photovoltaic power plant, after the termination of the contract for the sale of the produced electricity into the distribution network, could work perfectly as a self-sufficient power plant for the needs of the energy of the Ruše Sports Park. Insofar as it would be connected with other facilities to cover its own electricity consumption, the installation of an additional energy storage device would not be necessary.

3.4. The quantity of electricity sold in the distribution network

The tables below will show the actual amounts by month in 2017 of the generated electricity in kWh that were sold to the distributor in the network. Table 1 lists monthly differences at the meter point administration number 252647 photovoltaic panels on the roof of the Sports Park Ruse. Table 2 lists the monthly differences at the meter point administration number 253593 on the roof of the Ruše Sports Hall.

Meter point administration number: 252647			
date of reading	**higher daily tariff**	**lower daily tariff**	**Networking (total) kWh**
01.01.2017	259207	113655	0
1.02.2017	260773	114389	2300
1.03.2017	262473	115542	2853
1.04.2017	267157	116946	6088
1.05.2017	270345	119331	5573
1.06.2017	277164	122623	10111
1.07.2017	281808	124809	6830
1.08.2017	285790	125994	5167
1.09.2017	290335	127423	5974
1.10.2017	293688	128926	4856
1.11.2017	296608	130301	4295
1.12.2017	298023	131143	2257
1.01.2018	299341	132323	2498
			58802

Graph 5: Total amount of electricity sold in the network in kWh at Ruse Sports Park

Meter point administration number: 253593			
date of reading	**higher daily tariff**	**lower daily tariff**	**Networking (total) kWh**
01.01.2017	161524	71695	
1.02.2017	161773	71847	401
1.03.2017	162924	72679	1983
1.04.2017	166696	73830	4923
1.05.2017	169770	76093	5337
1.06.2017	176088	79134	9359
1.07.2017	180243	81089	6110
1.08.2017	181929	81335	1932
1.09.2017	184225	82140	3101
1.10.2017	186062	82811	2508
1.11.2017	188168	83817	3112
1.12.2017	189059	84209	1283
1.01.2018	189500	84611	843
			40892

Graph 6: Total amount of electricity sold in the network in kWh at Ruse Sports Hall

The total quantity of electricity produced in 2017 was 99,694.00 kWh. From the simulated calculation amount of 114,050.00 kWh, the difference is 12.6%. The difference is due to the annual difference in solar radiation and the deterioration in efficiency compared to the first year of operation of the plant.

Date of reading	**Ruše Sports Park**	**Ruše Sports Hall**	**Networking (total) kWh**
01.01.2018	0		
1.02.2018	2341	1392	
1.03.2018	1134	458	1592
1.04.2018	2595	1631	4226
1.05.2018	6631	8431	15062
1.06.2018	6303	3162	9465
1.07.2018	6061	4173	10234
1.08.2018	6860	4614	11474
1.09.2018	6805	4284	11089
1.10.2018	5643	4454	10097
1.11.2018	2841	3093	5934
1.12.2018			
1.01.2019			
			79173

Table 7: Total amount of electricity sold in the network in kWh between March and November 2018

The actual generated and commissioned amount of electricity in the network during the measurement period between March and November 2018 was 79,173 kWh, while the measured on the meters was only 36,075 kWh, which represents an error of 55% compared to the actual data.

3.5. Estimated investment and costs in a photovoltaic power plant

A rough estimate of an investment in a 100 kW photovoltaic power plant is 1100 € / kW of power, totaling € 110,000.

For 15 year crediting, the total amount paid by the borrower is € 126,722.20. All calculations were made on the basis of the average electricity price in 2017, ie EUR 0,1185 / kWh, and the actual production and electricity generated in the distribution network in 2017, totaling 99,694.00 kWh.

The table below shows the cost savings of the first year in EUR at 15-year funding. We find that savings are positive. Because of the rise in electricity prices in 2018 and the forecast for future rises, the savings will increase.

Calculation of the cost of a photovoltaic power plant	Cost of electricity consumed before the investment in EUR	Financing cost per year in EUR	Energy cost savings in EUR	Cost savings in EUR
Električna energija	55.330,73	8.448,13	11.813,74	3.365,85

Table 8: Costs of photovoltaic plant

3.6. Determining the performance of investment

The essence of the justification of investment decisions is to measure the eligibility of using money for a particular project. Static or dynamic methods can be used to determine the performance of an investment. Static methods do not take into account the time in their analyses, they consider a certain situation in the investments and the results of the investment, while dynamic methods take into account the time and it is one of the key elements in assessing the return on investment, monitoring of investments and operating results over a period of time.

3.7. Return period of funds invested

The definition of return of invested funds is the time period in which investment costs are reimbursed through returns. So the time of return is time needed for an investment with cash inflows to cover its initial contribution. If we want to calculate this indicator, we need the anticipated annual production of electricity in kWh and the redemption price, or in the case of self-supply, the price of energy saved. From these two data, annual income can be calculated, divided by the initial investment, and the return period of the investment is obtained.

Investment value: 126.722,20 €

Electricity production in 2017: 99,694.00 kWh
Price of energy saved: 0,1185 € / kWh

Annual revenue: 99,694.00 kWh x 0,1185 € / kWh = 11,813.74 €

Return period = 126,722.20 € / 11,813.74 € = 10.73 years

On the basis of the calculation, the investment in the photovoltaic power plant should be repaid in 10,73 years.
The remaining period of up to 15 years will be all production and the total net annual income is 4,27 years x 11,813.74 € = 50,444.67 €.

Our calculation is based on the actual annual production of electricity in kWh of the solar power plant sold in the distribution network.

3.8. Profitability on invested funds

The profitability of the investment is shown by the ratio between profit and invested capital in percentages. The percentages measure the success or failure of the investment.

For the calculation of profitability, we need data on annual income and depreciation rate, with which we obtain net profit per year. For this reason, the depreciation plan for our photovoltaic power plant will be presented in the table below.

Investment: 126.722,20 €
Annual revenue: € 11,813.74
Depreciation: 8,448.15 € (15 years)

Net profit = 11,813.74 € - 8,448.15 = 3,365.59 €

Profitability:

a. $\frac{100*average\ yield}{initial\ value\ of\ the\ investment} = \frac{100*8.448,15}{126.722,20} = 6,67\ \%$

b. $\frac{100*average\ yield}{initial\ value\ of\ the\ investment} = \frac{100*8.448,15}{63.361,08} = 13,33\%$

c. $\frac{100*average\ return\ on\ year\ 3}{initial\ value\ of\ the\ investment\ in\ year\ 3} = \frac{100*8.448,15}{109.825,90} = 7,69\%$

Interreg Mediterranean Pegasus
Project co-financed by the European Regional Development Fund

	Net profit in €	Book value at the beginning of the year in €	Carrying value at end of year in €	Average book value in €
Year 1	8.448,15	126.722,20	118.274,05	122.498,13
Year 2	8.448,15	118.274,05	109.825,90	114.049,98
Year 3	8.448,15	109.825,90	101.377,75	105.601,83
Year 4	8.448,15	101.377,75	92.929,60	97.153,68
Year 5	8.448,15	92.929,60	84.481,45	88.705,53
Year 6	8.448,15	84.481,45	76.033,30	80.257,38
Year 7	8.448,15	76.033,30	67.585,15	71.809,23
Year 8	8.448,15	67.585,15	59.137,00	63.361,08
Year 9	8.448,15	59.137,00	50.688,85	54.912,93
Year 10	8.448,15	50.688,85	42.240,70	46.464,78
Year 11	8.448,15	42.240,70	33.792,55	38.016,63
Year 12	8.448,15	33.792,55	25.344,40	29.568,48
Year 13	8.448,15	25.344,40	16.896,25	21.120,33
Year 14	8.448,15	16.896,25	8.448,10	12.672,18
Year 15	8.448,15	8.448,10	0	4.224,05

Table 9: Planned amortization plan for the Photovoltaic Power Plant Ruše Sports Park

3.9. Total return index

Total return index is the ratio between the total return on investment and investment expenditure. The greater the ratio or more than the units of total return on the basis of the unit of investment expenditure, the investment will be more successful. To calculate, we need the initial investment and the sum of all returns per year.

Total return in 15 years: 3.365,59 x 15 = 50,483.85 €

Total return index = 97,153.68 / 126,722.20 = 0.77

Only amortization was taken into account in the calculation. Other costs, such as interest costs, a distribution cost for electricity are omitted because of the simplification of the calculation, because the data do not play a greater role in the calculation of these two indicators, despite a slightly worse final result.

3.10. Net Present Value (NPV)

The net present value is the difference between discounted cash flow during all income and discounted cash flow during all outcomes of an investment. A key element in this method is the discount rate that allows us to calculate the present value of future cash flows. The discount rate tells us how much is 100€ in the next year worth the investor this year. Usually the discount rate is taken into account as

Interreg Mediterranean Pegasus
Project co-financed by the European Regional Development Fund

the amount of the bank interest rate, which is also most expedient in case of investing with bank loans. If the investment is financed with own funds, the discount rate is equal to the opportunity cost. In case investment is invested with a combination of own funds and investments with bank loans, we use the arithmetic mean of both interest rates.

The net present value is calculated using the following formula:

$$NPV = \sum_{i=1}^{T} \frac{D_i}{(1+r)^i} - \sum_{i=1}^{T} \frac{V_i}{(1+r)^i}$$

NPV = net present value

D_i = yield in i-th period i = 1,2 ... ..T

V_i = investment in the i-th period 1 = 1,2 ... .T

r = discount rate

1 / (1 + r) = discount factor

Discount rate: 1.95%

I0 = 126,722.20 €

Annual revenue: € 11,813.74

NPV(1,95%) = $\frac{11.813,74}{1,0195^1} + \frac{11.813,74}{1,0195^2} + \frac{11.813,74}{1,0195^3} + \frac{11.813,74}{1,0195^4} + \frac{11.813,74}{1,0195^5} + \cdots + \frac{11.813,74}{1,0195^{15}} - 126.722,20 = 25.645,02$ €

The net present value of our photovoltaic power plant is € 25,645.02. We cannot predict the results after the expiration of 15 years, because electricity prices for this period cannot be predicted exactly.

3.11. Internal rate of return

The internal rate of return is that discount rate, which equals the present value of return on investment and the present value of investment. With this method, we do not anticipate a discount rate (as with a net present value), but we find it. Repeat this process for as long as the net present value is not equal to zero. We therefore calculate it using the experiment and error method.

$0 = \sum_{i=1}^{T} \frac{D_i}{(1+IRR)^i} - I^i$ = 0

IRR = internal rate of return

D_i = yield in i-th period i = 1,2 ... ..T

I = investment cost

Initial investment	-126.722,20
Year 1 Revenue	11.813,74
Year 2 Revenue	11.813,74
Year 3 Revenue	11.813,74
Year 4 Revenue	11.813,74
Year 5 Revenue	11.813,74
Year 6 Revenue	11.813,74
Year 7 Revenue	11.813,74
Year 8 Revenue	11.813,74
Year 9 Revenue	11.813,74
Year 10 Revenue	11.813,74
Year 11 Revenue	11.813,74
Year 12 Revenue	11.813,74
Year 13 Revenue	11.813,74
Year 14 Revenue	11.813,74
Year 15 Revenue	11.813,74
Internal rate of return (IRR)	5%

Table 10: Table of calculation of the internal rate of return

The initial investment in the calculation represents a negative number. Annual revenues represent a positive value. The calculated internal rate of return is 5%. The investment is justified.

3.12. Findings on the eligibility of an investment

From the previous calculations of the indicators we find the following:

The investment will be repaid in 10.73 years. It is generally known that photovoltaic power plants are a good source of the future, since the sun is a free energy source and that the investment in such a power plant is recovered around 10 years. The life of solar power plants is up to 30 years.

NPV investments are positive at 1.95% discount rate, which means that after covering all the costs over the lifetime of the investment (15 years), we remain 25.645.02 €, calculated to our present time.

The ISD is 5%, which is more than the banking or borrowing rate for the own funds invested.

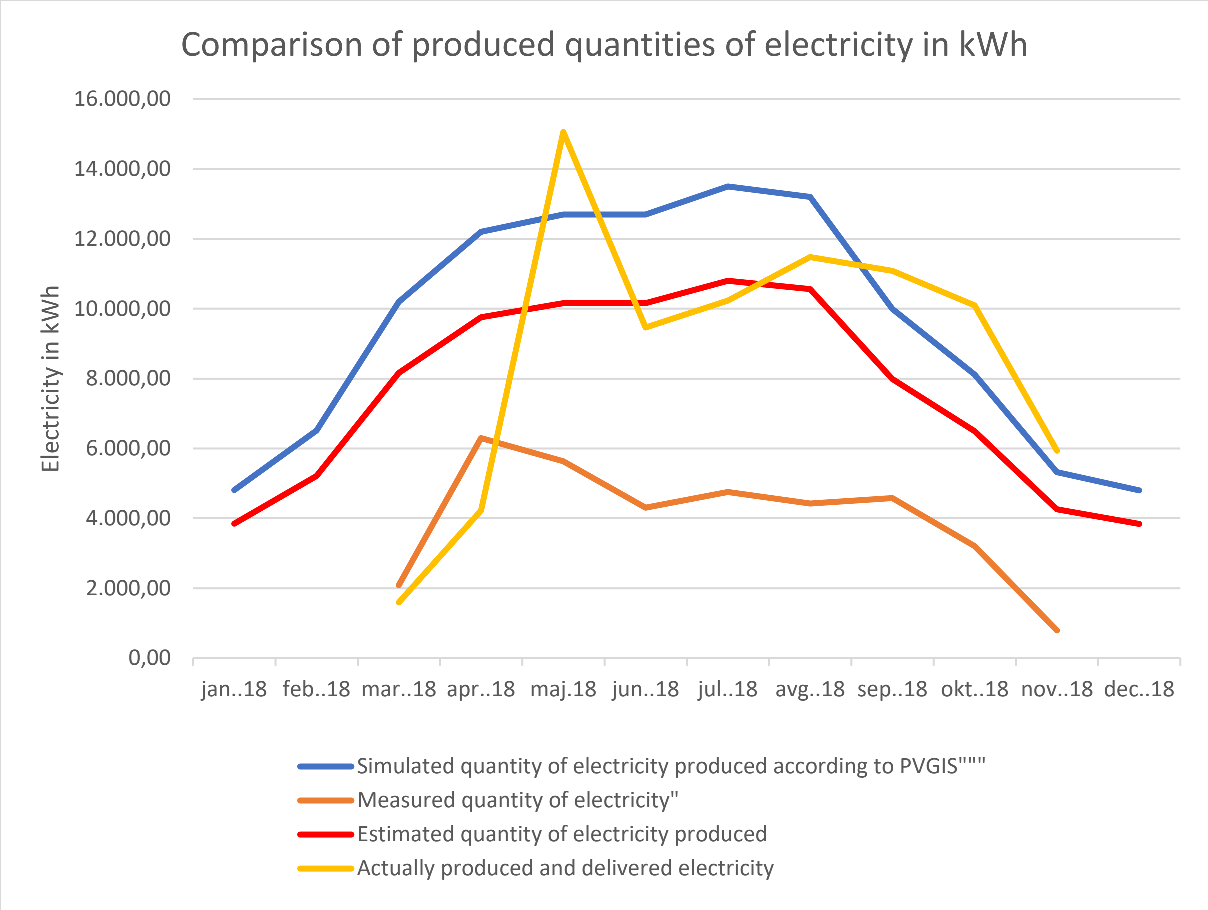
It can be seen from the calculated indicators that this investment in a photovoltaic power plant, on the basis of starting points and assumptions, and from the point of view of economy, is very interesting. Using a self-sufficiency model with internal connection and consumption, at the given moment, the net present value turned out to be positive, and thus the investment in the solar power plant achieved the high cost-effectiveness of such a project.

3.13. Analysis of the performed measurements

Below is a graph (Graph 10), which shows the comparison between the simulated forecast quantities of produced electricity, the estimated quantity of energy produced after 10 years with the losses taken into account, the measured quantity on the meters, and the actual quantity sold in the distribution network in 2017.

The measured data on the Ruše Sports Park meters do not coincide with the measurements and deviate by more than 50% and can not be used in economic analysis. The reasons for incorrect operation of the measurements can be more than the failure of the inverters, faults, interruption in the installation, poor optimization of the measurement system and software, etc.

The most accurate insight is the actual quantity of electricity produced after months sold in the distribution network in 2017.



Graph 9: Comparison of the produced electricity of photovoltaic power plants

In the graph 10, in the curve of the actual measured quantities of electricity, we can notice higher fluctuations due to different solar irradiation by months.

4. Technical and economic aspect of the installation of CHP

At this point, we would like to check whether, due to the large demand for thermal energy at the Ruše Sports Park, it would be sensible to invest in cogeneration for the production of electricity and heat in case of own use of electricity and heat. Cogeneration devices for the simultaneous production of electricity and heat (hereinafter referred to as CHP) must be dimensioned in accordance with the heat consumption (below 90 ° C) and at the same time they must be dimensioned to provide a bandwidth of at least 4,000 hours per year. The good thing about CHP is the very high total primary energy utilization of more than 80% which is unsuitable for more than, for example, Conventional power generation with 35% efficiency. We have no losses in the distribution of heat and not in the distribution of electricity for our own electricity consumption.

4.1. Reconstruction of the heat supply system with an investment in cogeneration

The study showed that a small cogeneration plant with an electric power of 50 kW and 81 kW of heat power would be suitable for the existing building. The CHP would be connected to the heat and hot water storage boiler room. Existing gas boilers, if necessary, can cover heating points.

In order to make the investment profitable and the operation would make sense, it depends on several factors: electricity prices, natural gas prices, and also depends heavily on state support for the production of electricity and the discharge of electricity surplus as well as the value of the investment.

In our case, an economic calculation of the sensitivity of the investment for the installation of cogeneration will be made exclusively for own energy consumption needs and without connection to the distribution network. In this case, they would not receive funding from the state and would not have guaranteed purchase of electricity.

4.2. Technical specifications for cogeneration

For the calculation, a cogeneration unit of Viessmann Vitobloc EM-50/81, which operates on natural gas, has a heat output profile based on the heat profile and has a working power of 50 kW electrical and 81 kW of heat energy. In operation, it uses 15m3 / h of natural gas powered by a 4-cylinder gas engine with an efficiency of 90.3% (Hi), which has substantially improved by upgrading the flue gas condensation (theoretically by definition even to 103%). The expected lifetime of the device is 50,000 hours (13 years), which require a major investment in the repair (overhaul) of the device.

The investment in the purchase of cogeneration, according to the manufacturer, amounts to 75,000 € + VAT = 91,500 € and a maintenance cost of 1,27 € / h + VAT, which includes all anticipated interventions in operation of 4000 hours a, totaling 10 years.

Table 11: Basic parameters of the SPTE unit

Parameter for EM 50/81	Quantity	Unit
Rated electrical power	50	kWe
Rated thermal power	81	kWt
Total efficiency	90,3	%
Heat efficiency	55,9	%
Electricity efficiency	34,5	%
Gas consumption	145	kWh/h

Interreg Mediterranean Pegasus
Project co-financed by the European Regional Development Fund

4.3. A rough estimate of the CHP investment

VARIANT 2	Value in €
Vitobloc 200 typ EM-50/81	91.500,00
Connection and commissioning (electric, hydraulic, gas)	4.500,00
Machine installations (Heat exchanger, pipe connections (water, gas), pumps for circulation, fittings, calorimeter, gas meter, flue gas capacitor, chimney with CHP connection, hot water accumulator, thermal insulation and work)	35.000,00
Electrical installations (supply cables, electric lock cases), protection, gas alarm + el. mag. vent., project documentation)	12.500,00
TOTAL	143.500,00 €

Table 12: A rough estimate of the investment in CHP

4.4. Calculation of the eligibility of the investment

Cogeneration can theoretically operate 365 days x 24 hours = 8760 hours per year. Real working hours are reduced by at least 500 hours due to regular shutdowns due to service. Services are performed every 1000 hours of operation and due to oil change every 2,000 hours.

On the basis of all known and recommended data, we decided that the cogeneration unit would operate 6500 hours a year.

The operation of the device is optimal when the gas engine operates between 50% and 100% of rated power.

Unit	Rated power / KW	Working units h / annually	Produced KW / annually
Qel	50	6.500	325.000
Qtpl	81	6.500	526.500
Together			851.500

Table 13: Estimated generated electricity and thermal energy

In the average operation of the cogeneration plant 6,500 hours a year and its nominal power of 50 kW of electricity, 325,000 kW of electricity will be generated, and at a net power of 81 kW of thermal energy, 526,500 kW of heat will be produced.

4.5. Economics of investments in CHP

The economic calculation of the CHP investment was made in the course of the operation of cogeneration of 6,500 hours per year for the known use of electricity and heat in 2017. Based on the use of energy, the average energy prices were calculated in the table below.

Base prices for use and costs of electricity and heat			
		Electricity	**Heat**
Consumption 2017	**kWh**	477.504,00	1.205.414,00
Cost energy	**EUR**	37.278	52.427
Cost Power	**EUR**	17.557,90	8.414,16
Remaining cost	**EUR**	485,66	957,00
Cost together	**EUR**	55.321,38	61.798,18
Cost energy	**EUR/kWh**	0,0781	0,0435
Cost Power	**EUR/kWh**	0,0368	0,0070
Remaining cost	**EUR/kWh**	0,0010	0,0008
Cost together	**EUR/kWh**	0,1159	0,0513

Table 14: Base prices for use and costs of electricity and heat

Total heat output CHP = Number of hours of operation x Heat power = 6500 x 81 = 526.500 kWh

Based on the assumption that cogeneration unit consumption is 145 kWh/h of natural gas by total cogeneration efficiency of 90.3% and 6500 operating hours, the consumption is:

$$V_{year} = V_h * t * \frac{1}{\eta} = 145 \frac{\mathrm{kWh}}{\mathrm{h}} * 6500\mathrm{h} * \frac{1}{0,903} = 1.043.743\mathrm{kWh}$$

t= operating time of the cogeneration unit (h)

η= machine efficiency

V_h = consumption of natural gas per year

Based on the amount of natural gas and the price of 0,0513 EUR / kWh, the annual cost of natural gas can be determined.

Cost = 1.043.743 * 0.0513 = 53.544 EUR

Assume that the rest of the required annual heat is carried out by a boiler on natural gas.

The boiler room on natural gas located in the basement covers the needs for hot sanitary water, pool heating, and transmission and ventilation losses. The I.VAR INDUSTRY hot-water boiler type TRISPACE 580 is installed. The maximum boiler output is 580 kW. The boiler is equipped with a natural gas burner manufactured by BALTUR type TBG 80 LX PN ME with a gas line DUNGS M412-S30 B01 ME. The boiler efficiency is 91.5% according to the manufacturer's data.

The difference between the required annual heat of 1,204,414 kWh and produced by cogeneration is 1,205,414 - 526,500 = 678,914 kWh.

Cost of additional heating with boiler after investment = 678,914 * 0,0513 = 34,806.1 EUR

The cost of electricity after the investment is reduced from a total of EUR 55,321.4 to EUR 17,675.20.

We also have to consider the maintenance cost, which is 1.27EUR / h + VAT:

Boiler maintenance cost = 10,071.1 EUR at 6500 h operation of the device for the first 15 years.

Since the CHP will operate for self-handling and will not sell electricity, we calculate the total annual electricity revenue on the basis of the average electricity price in 2017. The total electricity produced in operation of 6500 hours with a power of 50 kWel is 325,000 kWhel. Taking into account that so much energy would be saved and the purchase price of electricity would be 0,1159 € / kWh, the total CHP electricity revenue would be = 325,000 * 0,1159 = EUR 37,667.5.

A rough estimate of the investment in the construction of the CHP and the arrangement of the boiler-room would-be EUR 143,000. The cost of investment in CHP in the case of lending with a total annual interest rate of 2.8% is EUR 176,573.20, which is calculated annually at EUR 11,771.55.

	Pre-investment cost (gas boiler)	**Cost after investment (gas boiler)**
Thermal energy in EUR	61.798,18 €	34.806,10 €
Electricity in EUR	55.321,38 €	17.675,20 €
Maintenance cost		10.071,10 €
Lending cost		11.771,55 €
Cost after investment per CHP		53.544,00 €
Together	117.119,56 €	127.867,95 €

Table 15: After and pre-investment cost

The difference between revenue and expenditure of energy including all maintenance and credit costs = 117.119,56 € - 127.867,95 € = -10.748,39 €

The return on investment is negative. At the current prices of energy products, the investment has a negative return.

The calculations show that the CHP system in the total operating time of 6500 h per year from the economic point of view with its own financing in order to self-sustain the produced heat and electricity without an agreed energy contracting power supply and without guaranteed purchase of electricity would not be economically justified.

Necessary price and price difference for cost-effective cogeneration

	Necessary cost for profitability
	EUR/kWh
Electricity	0,1510
Gas	0,0513

Needed difference in the price of energy products for profitability	Missing difference for profitability
EUR/kWh	**EUR/kWh**
0,10	0,0354

Table 16: Necessary price and price difference for cost-effective cogeneration

For a profitable cogeneration operation, a price difference of 0.1 EUR / kWh would be required, which means that there is a missing difference in profitability of 0.0354 EUR / kWh.

5. The technical and economic aspects of the installation of solar power plants

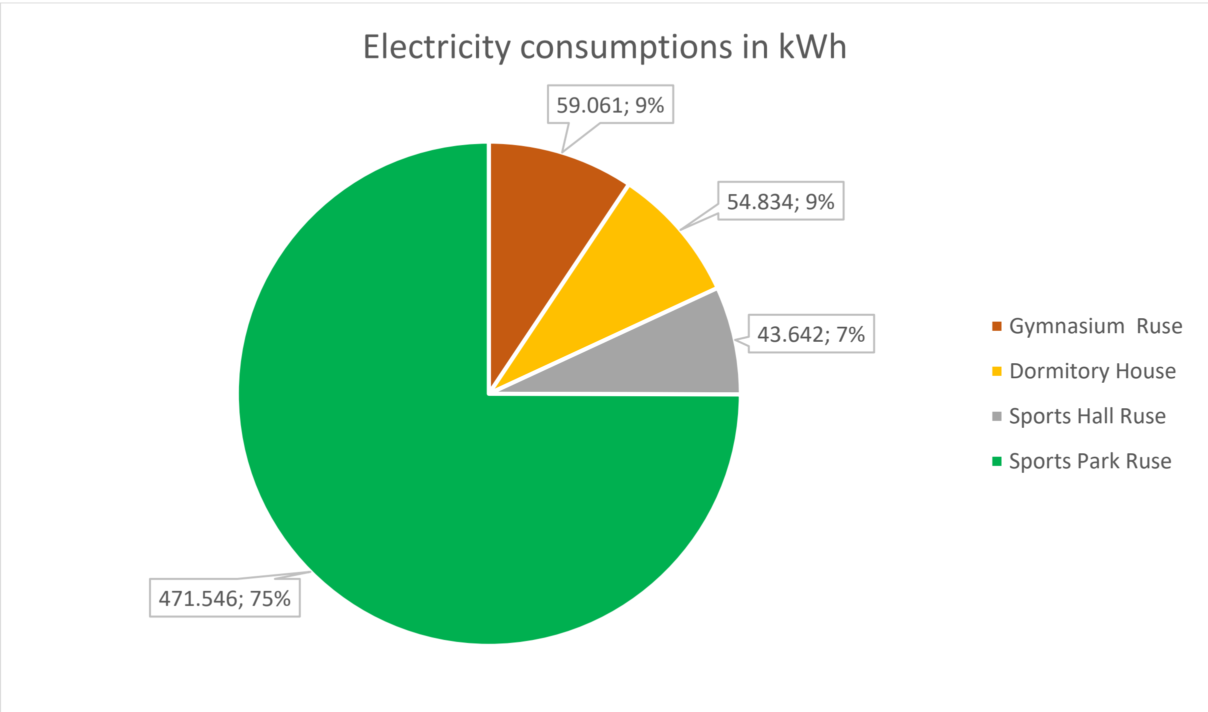
5.1. Investment in a solar power plant

With the adoption of the new Decree on the self-supply of electricity from renewable energy sources in Slovenia, self-supply of electricity has become a trend and a profitable investment. The installation of a solar power plant can reduce electricity costs by 75% and the investment will be repaid in 8-10 years due to subsidies from the Eco Fund.

A 1kW photovoltaic module generates an average of 1100 kWh of electricity per year. The lifetime of the solar power plant reaches 30 years or more. In addition to the basic solar power plant warranty of 10 to 25 years, most providers also offer additional warranties, such as a non-leaky roof warranty.

There are virtually no downsides to a solar power plant, it is an investment that is definitely worth it. Of course, when deciding to invest in a solar power plant, a detailed analysis of the location of the building and the number of hours of irradiation at the location at which we want to erect the plant must be made.

In the case of the Pegasus project at the pilot site of the Ruše Sports Park, we first checked the electricity use of all 4 buildings in 2018. Graph 11 shows the electricity consumption of each building of the microgrid.

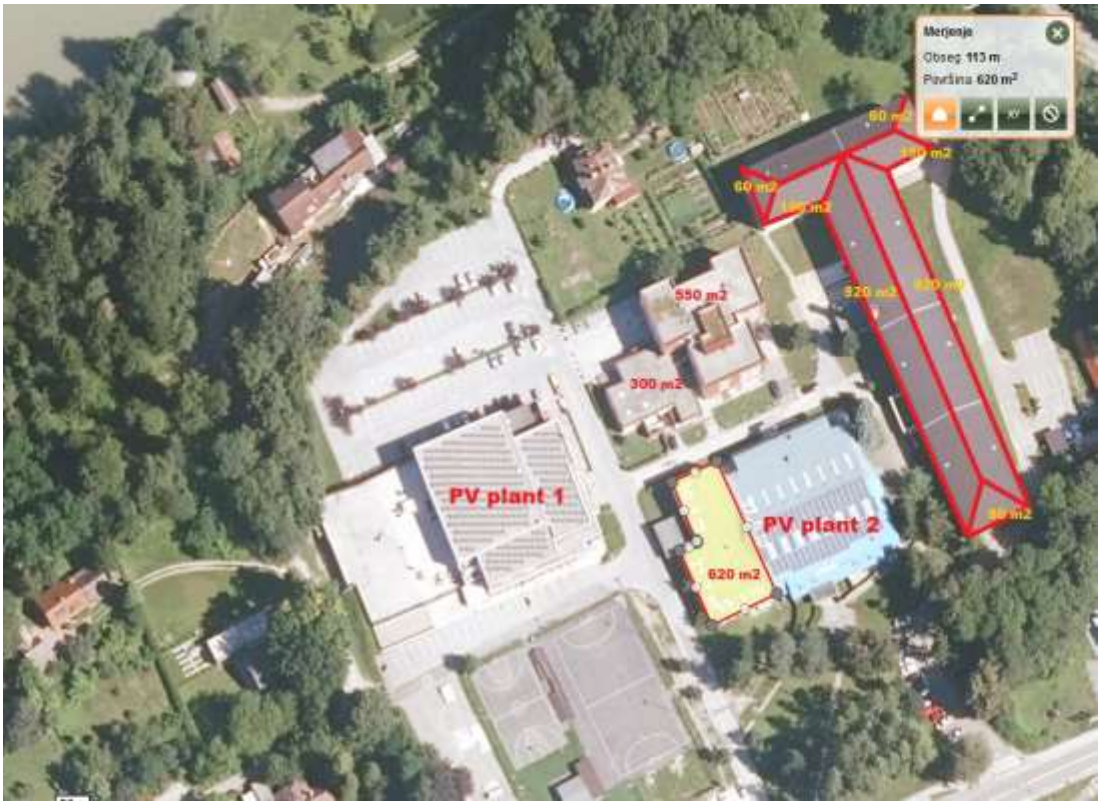


Graph 10 Electrical consumption in the microgrid of the Ruše Sports Park

Interreg Mediterranean Pegasus
Project co-financed by the European Regional Development Fund

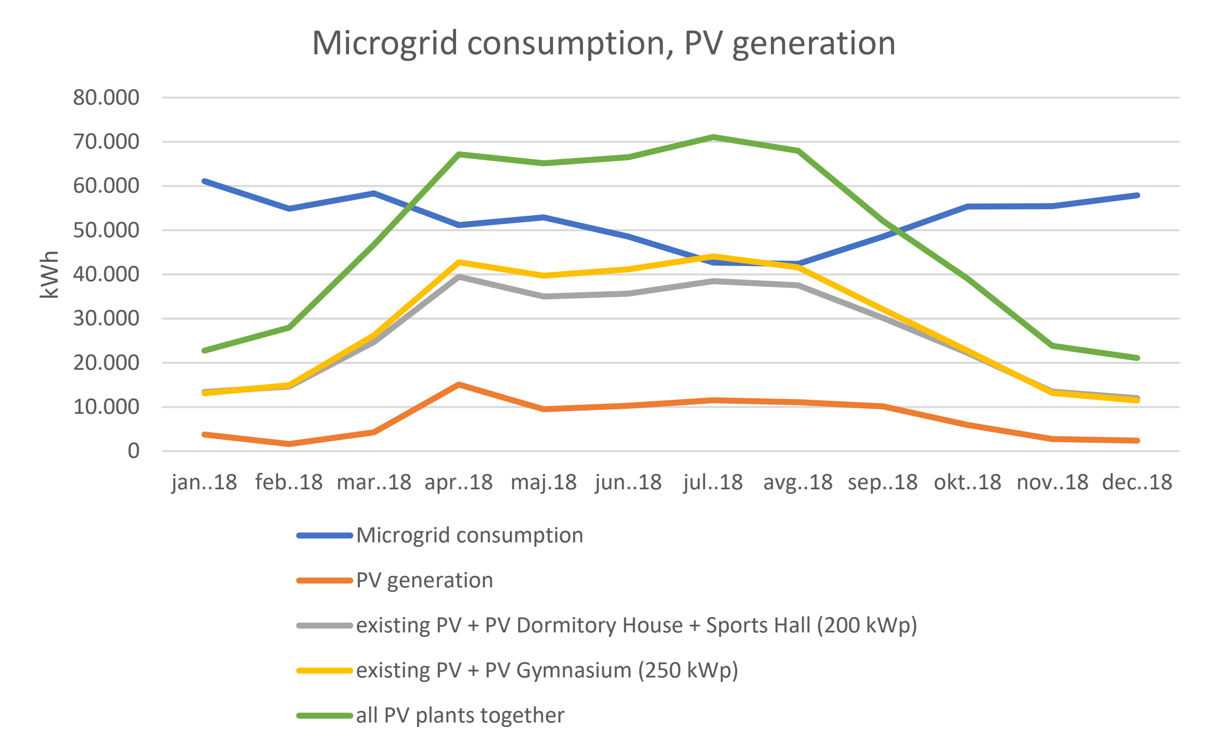
In 2018, the total electricity consumption of all buildings was 629.083 kWh. Photovoltaic power plants on the rooftops of Ruše Sports Park and Ruše Sports Hall produced a total of 88.038 kWh of electricity, representing only 14% of total self-sufficiency. If we would like to meet the electricity needs on an annual basis, we would need to produce another 541.045 kWh of electricity. The size of the photovoltaic module is 1.65 m2. We choose a power of 300 W. In order to achieve self-sufficiency of the building, it would be necessary to install a total of 1803 modules with a total surface area of 2975 m2. The surface of the corresponding roofs should be considerable.

After a quick look at the Atlas Environment map, several roof surfaces appear as a possible location for the installation of a solar power plant. The roof surfaces are symbolically marked, and the suitability of the site itself should be carefully checked.



Picture 6: Symbolic representation of possible roof surfaces for the installation of a solar power plant

Based on the orientation of the roofs and the gains of solar radiation, PVGIS photovoltaic geographic information systems verified and evaluated electricity production. Graph 12 shows the electricity consumption and production curves. The blue curve shows the annual electricity consumption of all buildings. The orange curve in the graph shows the current production of a 100 kWp solar power plant. The yellow and gray curves show the production of power plant installed on a sports hall, dormitory house or gymnasium rooftop. If there was installed a 250 kWp solar power plant on the east and west side of the roofs of the Ruše gymnasium, we would reach and exceed the demand for electricity in the summer months. If a power plant of 450 kWp is installed, as shown by the green curve on the graph, in the summer months it would produce 171,253 kWh of surplus electricity and in winter months it would generate 140,890 kWh of electricity deficit. To reach self-sufficiency of microgrid we would still require 30.363 kWh of electricity in this case.



Graph 11: Electricity Consumption and Production in the Micro Network of the Ruše Sports Park

The first goal would be to set up at least a 250 kWp power plant that would meet most of the electricity needs at least during the summer months.

5.2. Calculation of electricity prices according to the LCOE methodology (levelized cost of energy)

Based on the calculation, it was found that the current average purchase price of electricity from the grid for all four buildings is equal to 0.12 EUR / kWh.

LCOE, or leveled energy costs, is a term that describes the cost of electricity per kWh of payment current, which has the same present value as the total cost of constructing and operating a generating plant over its lifetime and it is one of the most commonly used metrics of the residential solar industry.

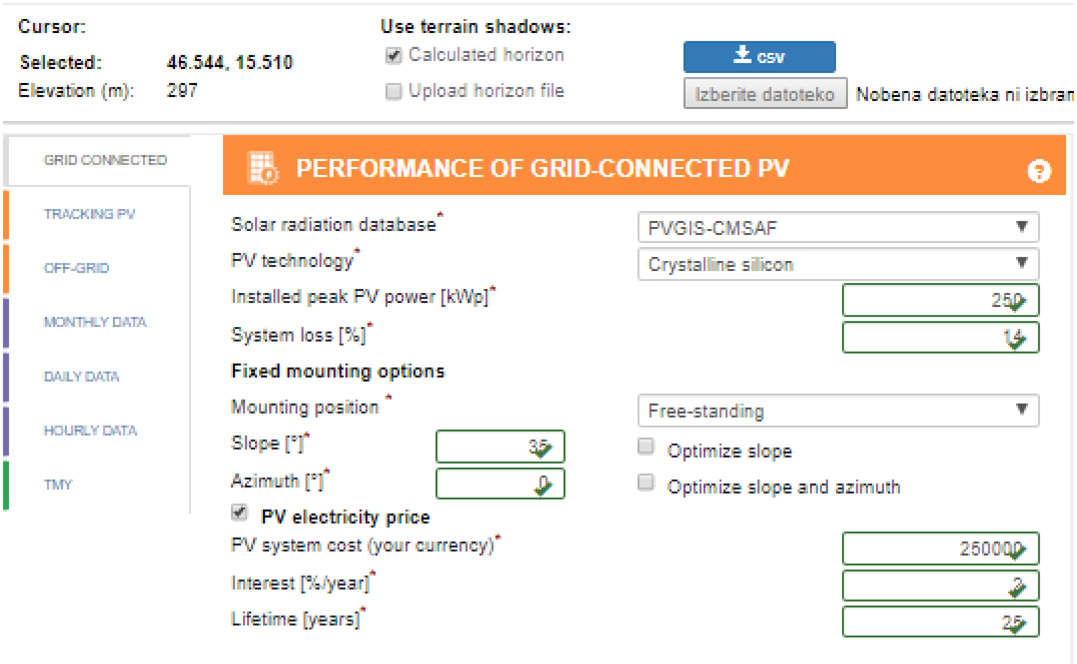
In the most basic level, the Levelized Cost of Energy is the lifetime cost of a solar installation, divided by the amount of energy the installation generates.

The calculation was made using a PVGIS LCOE calculator. To get the energy price, we had to enter three factors: PV system cost in EUR, Interest rate in %/year and Lifetime in years.

We have selected the total cost of the system worth EUR 250,000 including PV system components (PV modules, mounting, inverters, cables etc.) and installation costs (planning, installation....).

For the interest rate you pay on any loans needed to finance the PV system we chose 2%. This assumes a fixed interest rate on the loan which will be paid back in yearly installments for the lifetime of the system.

For the expected lifetime of the PV system we chose 25 years. This is used to calculate the effective electricity cost for the system. If the PV system happens to last longer the electricity cost will be correspondingly lower.



Summary

Provided inputs:	
Location [Lat/Lon]:	46.544, 15.510
Horizon:	Calculated
Database used:	PVGIS-CMSAF
PV technology:	Crystalline silicon
PV installed [kWp]:	250
System loss [%]:	14

Simulation outputs:	
Slope angle [°]:	35
Azimuth angle [°]:	0
Yearly PV energy production [kWh]:	286000
Yearly in-plane irradiation [kWh/m²]:	1420
Year to year variability [kWh]:	19100.00
Changes in output due to:	
Angle of incidence [%]:	-3
Spectral effects [%]:	1.5
Temperature and low irradiance [%]:	-5.2
Total loss [%]:	-19.7
PV electricity cost [per kWh]:	0.062

Picture 7: Calculation of PV electricity cost per kWh.

The calculated electricity price per kWh over the lifetime of the power plant is thus 0.062 EUR / kWh.

If we compare this price with the price of the electricity we pay, the difference is 51.7%.

Interreg Mediterranean Pegasus
Project co-financed by the European Regional Development Fund

6. Conclusion

Based on the performed economic analysis, we have established that in calculation of the economic indicators, the net present value turned out that at a given moment from the point of view of self-supply with electricity, the investment in the implementation of the solar power plant is paid as we get a positive net present value.

The feasibility study for the installation of a cogeneration unit for heat and power has proved to be economically unjustified since the payback period is negative due to the high investment cost. If the difference between gas and electricity prices would increase in the future and the amount of investment would decrease slightly, the integration of cogeneration could become profitable.

If we would like to provide an even greater share of RES and provide an even greater share of our own produced electricity, it would be wise to consider the additional solar power plant on the remaining buildings of the Dormitory House and the Ruše Gymnasium.

Firstly, the production of renewable energy from photovoltaics is fluctuating and can be very flexible. If we would like to increase the security of supply in the micro network of the Ruše Sports Park and achieve cost-effective electricity supply in the case of supply from the distribution network and also have the possibility to cut power in the peaks of electricity demand, it would certainly have been reasonable today to analyze the installation of additional energy storage. This storage of electricity would not be long-term, but energy would be stored in the storage rooms for a short time, and therefore such a system would need to be accurately simulated and, on the market, also optimum functioning regulators and smart measuring systems with feedback on the phone, a computer that would continually manage all the energy need to be found.

Photovoltaic plants are already effectively controlled with automatic intelligent measuring devices. The fact is, with the increase in the share of RES, the need for seasonal storage of energy will increase, and the storage units will become necessary for the operation of such a system. For all new battery technologies, a significant reduction in costs is expected, and it is now considered that the costs of Lithium ion storage of batteries are less than 10 ct / kWh.

It is also necessary to be aware that all investments cannot be made with own funds, and hence the forms of favorable lending and co-financing and the possibility of obtaining grants in the case of self-sufficient micro networks in the future would be necessary. With the implementation of micro networks, it would also be easier to gain experience with new storage technologies, and at the same time to achieve easier stabilization of the power grid.

Project co-financed by the European Regional Development Fund