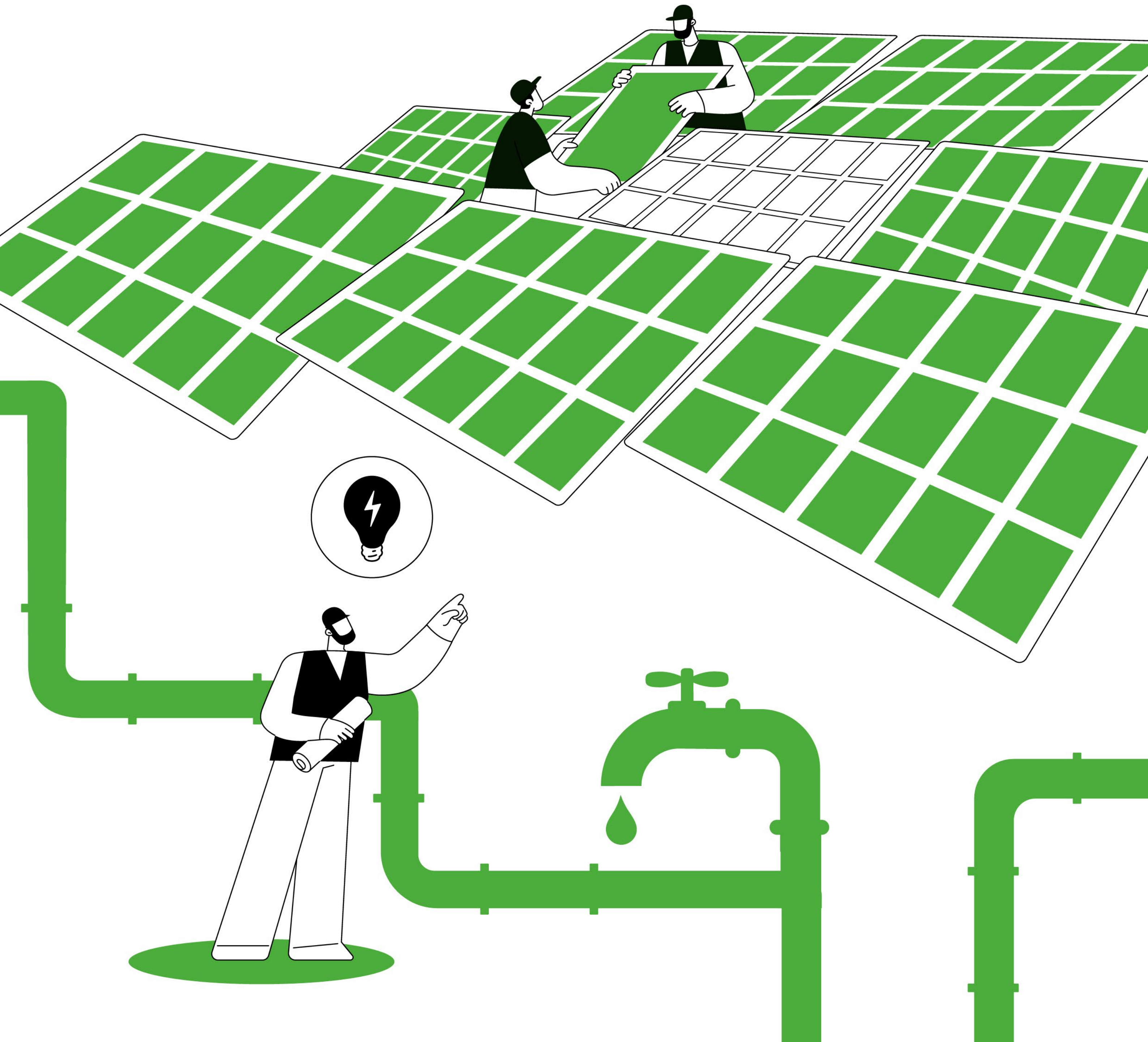
Odesa oblast
Ananiv city territorial community

PRELIMINARY FEASIBILITY STUDY

Installation of a solar power plant for the needs of backup power supply of the utility company «Ananiv - Water Utility of Ananiv City Council»



Project name		
Installation of a solar power plant for the needs of backup power supply of the utility company «Ananiv - Water Utility of Ananiv City Council»		
The address of the implementation object:		
Odesa oblast Ananiv city territorial community 47.734192, 29.966212; 47.732998, 29.958881		
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Contacts of the head of the water utility		
Voloshin Sergiy Mykolayovych Tel.: 0982374445, e-mail: kpan-vod@ukr.net		
Project idea	Installation of a solar power plant for the needs of backup power supply of the municipal enterprise «Ananiv - water utility of Ananiv city counci»	
Project implementation period	4-5 months	
Technical characteristics of the project	Option 1. Network SPP with a capacity of 150 kW Option 2. Hybrid SPP with a capacity of 150 kW with accumulator tanks with a total capacity of 240 kWh	
Main equipment and materials	PV panels Inverters Batteries	
	Network SPP 150 kW	**Hybrid SPP 150 kW**
Project cost (approximate)	221 408.6 EUR [1]	221 408.6 EUR
Reduction of energy consumption from the general network as a result of the project implementation	175 960.9 kWh per year	175 960.9 kWh per year
Reduction in energy consumption as a result of project implementation over the entire life cycle	3 080 781.6 kWh	3 080 781.6 kWh
Cost savings due to project implementation	30 427.4 EUR/year	30 427.4 EUR/year
Payback period	5.1 years	7.3 years
Reduction of greenhouse gas emissions as a result of project implementation (CO_2 equivalent)	87.9 tonnes/year	87.9 tonnes/year
Planned lifetime of the project	20 years	
Present value of electricity (LCOE)	0.08 EUR/kW	0.12 EUR/kW
Current electricity tariff [2]	0.17 EUR/kWh	

[1] All prices in UAH are converted at the rate of UAH 44.37 per EUR according to InforEuro data for July 2024 (InforEuro provides official monthly exchange rates of the European Commission for EUR, corresponding exchange rates for other currencies and historical exchange rates dating back to 1994).

[2] According to the energy market, the average electricity tariff for utilities in 2024 is EUR 0.17 per 1 kWh. This tariff includes transmission and distribution costs, including VAT.

1. BRIEF DESCRIPTION

Ananiv Water utility of Ananiv City Council provides water supply and sewerage services to the Ananiv city territorial community, Odesa region. The number of individual customers receiving water supply services is 3 293. The number of people receiving water supply services is 7 389. There are 7 tanks to store clean water with a volume of 69 m³ each: one tank with a volume of 150 m³ and another tank with a volume of 350 m³. The total demand for water per month is 66 303 thousand m³. The main sectors of water consumption are domestic and industrial.

Consumption is expected to grow as forecast, which will be affected by a decrease in the price factor.

The length of the company's sewerage networks in Ananiv is 13.8 km. The length of street sewerage networks is 6.8 km, and intra-quarter sewerage networks are 7.0 km. Wastewater is supplied to the municipal sewage treatment plant (STP) through six sewage pumping stations (SPS).

Characteristics of sewage pumping stations (SPS):

- SPS-1 (Park) receives wastewater from Proletarska Street and Nezalezhnosti Street. The wastewater is then conveyed through 150 mm diameter ceramic pipes to the municipal sewage treatment plant (STP).
- SPS-2 (37 Pushkina Street) receives wastewater from Pushkina Street and Anosova Street and is supplied to the municipal sewage treatment plant through cast iron pipes with a diameter of 110 mm.
- SPS-3 (25 Nezalezhnosti St.) receives wastewater from Nezalezhnosti St. through 110 mm diameter cast iron pipes and delivers it to SPS-2.
- SPS-4 (42, Yevreyska Street) receives wastewater from Nezalezhnosti and Yevreyska Streets through 110 mm diameter cast iron pipes and delivers it to the STP.
- SPS-5 (Avtovokzal) receives wastewater from Nezalezhnosti Street, Heroiv Ukrayiny Street through ceramic pipes with a diameter of 150 mm and delivers it to the STP.
- SPS-6 (STP, 1 Bohdana Khmelnytskoho St.) supplies wastewater from the settling tank to the aeration tanks.

Municipal sewage treatment plants (STPs) include a complex of facilities for mechanical and biological wastewater treatment, drainage (dewatering) of sewage sludge. The installed capacity of the municipal sewage treatment plants is 0.7 thousand m³/day.

Composition of the municipal sewage treatment facilities:

- primary settling tanks 6.0 x 6.0 m in size - 1 pc.;
- receiving chamber - 1 pc.;
- aeration tanks - 2 sections;
- secondary settling tanks 10.0 x 2.0 m - 1 pc.;
- contact tanks 2.0 x 2.0 m - 4 pcs.;
- sludge platforms - 2 pcs.

The treated wastewater flows by gravity through a 400 mm diameter, 60 m long pipeline into the Tiligul River. The area of the treatment facilities is 0.94 hectares.

Energy consumption of the sewage and wastewater treatment system.

Title	2023 year		
	Energy consumption, kWh/year	Capacity, m^3/year	Specific energy consumption, kWh/ m3
Sewage and wastewater treatment system	kWh/m^3	28800	1,94

The utility company controls the technical condition of the engineering equipment of buildings and structures, issues permits and technical specifications for connecting consumers to centralized drinking water supply and sewage systems, as well as for reusing treated wastewater and sludge, subject to compliance with the maximum permissible concentration standards and maximum permissible discharge standards for pollutants. The ME restricts or terminates the operation of centralized drinking water supply facilities when there is a need to respond promptly to the deterioration of water quality in drinking water sources and the inability to bring it to the requirements of state standards, with notification of such disconnection and its reasons to local governments, local executive authorities and state sanitary and epidemiological service bodies, as well as consumers.

There is a 55 kW/h motor generator to power the water utility. It runs on diesel fuel in the absence of electricity supply.

2. DESCRIPTION OF SOCIAL AND DOMESTIC ISSUES TO BE ADDRESSED BY THE INSTALLATION OF THE SPP

The installation of a solar power plant at the artesian wells of the Ananiv Water Utility of the Ananiv City Council is important to solve a number of social and domestic issues. Given the emergency and planned power outages caused by damage and destruction of critical infrastructure as a result of russia's military aggression. This measure is crucial as it will reduce dependence on traditional sources that may be unstable or destroyed.

The 150 kW SPP on artesian wells will ensure that pumps can operate to lift water during power outages, which will ensure a stable supply of water to the population, as the main consumption sector is households. This is especially important in the context of regular power outages, as a stable supply of water is critical to ensure public hygiene and health. Installing a solar power plant on artesian wells will provide drinking water to people in the community. In the event of a power outage at the wells of neighboring communities and the constructed solar power plant, Ananiv Water utility of Ananiv City Council will be able to pour water into prepared tanks, which will provide water supply to neighboring communities with a population of 3 000 people.

In the absence of electricity, the sewage treatment plant (STP) that treats wastewater will stop working, leading to the release of contaminated water into the water body. As a result, the number of waterborne diseases will increase. Therefore, the installation of a SPP at the water utility's STP will ensure its continuous operation and access to water for 22 thousand residents of the community.

The use of renewable energy helps to reduce greenhouse gas emissions, which is especially important given the company's high energy consumption and will have a positive impact on the region's environment.

Thus, the installation of a SPP at the water utility Ananiv Water Utility of Ananiv City Council will help solve critical social and domestic problems, contribute to stable electricity and water supply, improve the quality of life of the population and reduce the environmental burden.

3. NEGATIVE IMPACT ON THE ENVIRONMENT

Negative impacts may occur after the end of their service life, in the process of panel recycling. Currently, there is no publicly available information on the technologies for recycling used panels in Ukraine.

4. ELECTRICITY CONSUMPTION

The main power equipment that accounts for the majority of energy consumption is 18 kW water pumps and 6 kW water pumps.

The annual electricity consumption for the last 4 years is shown in the table below:

	2019	2020	2021	2022	Average
Annual electricity consumption, kWh	378419	365384	463766	***625673***	**458310,5**

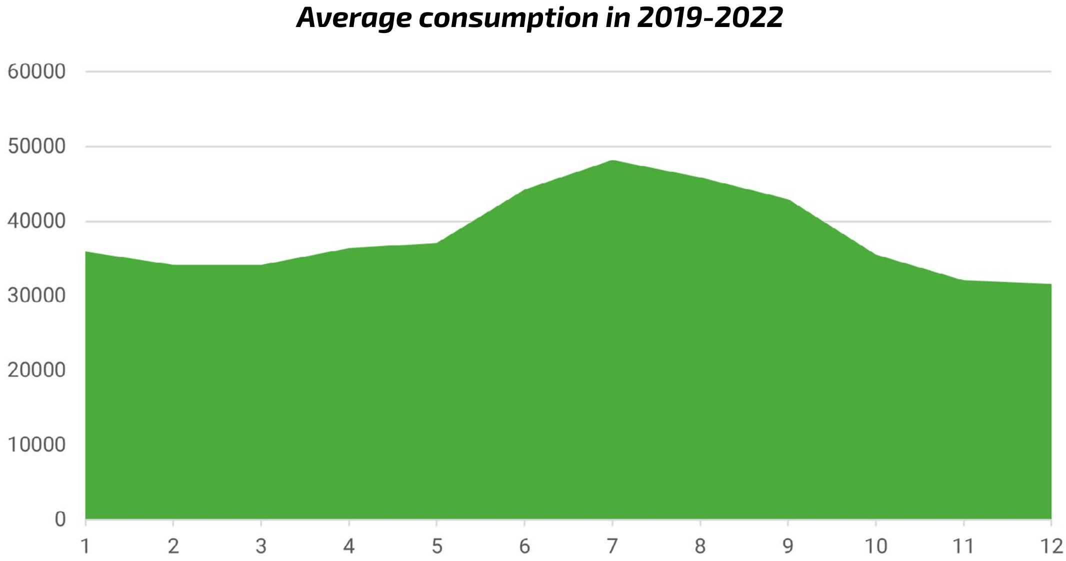
Annual consumption (averaged) is **458,310.5** kWh.

Electricity consumption by month during the year:

Year	Months												Total for the year
	1	2	3	4	5	6	7	8	9	10	11	12	
	Electricity consumption, kWh												
2019	33811	28489	27340	28568	34745	49722	34317	31169	29603	28483	24634	27538	378419
2020	27316	27460	25740	28469	29327	32567	33902	42913	33360	28994	25481	29855	365384
2021	34825	39057	42676	36705	36064	37552	45424	39674	37271	38995	37645	37878	463766
2022	47712	41527	40801	51919	48152	57322	79233	69865	71608	45626	40702	31206	625673
Середнє	35916.0	34133.3	34139.3	36415.3	37072.0	44290.8	48219.0	45905.3	42960.5	35524.5	32115.5	31619.3	458310.5

1 - January; **2** - February; **3** - March; **4** - April; **5** - May; **6** - June; **7** - July; **8** - August; **9** -September; **10** - October; **11** - November; **12** - December.

Monthly consumption ranges from 31 619.3 to 48 219.0 kWh.
Annual consumption (averaged) is 458 310.5 kWh.



5. PROPOSED SOLUTIONS:

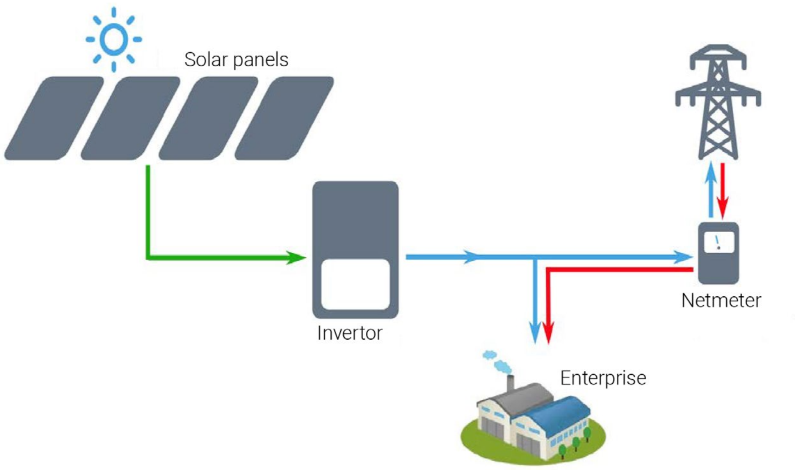
Consider the construction of a solar power plant (SPP) with a capacity of 150 kW, to provide a backup power supply. We will estimate, given the planned generation, the costs of installation and maintenance.

Two types of SPPs are considered: network and hybrid. The network SPP will be connected to the general power grid, which simplifies its use, but depends on the stability of the centralized power supply. In addition, a hybrid SPP will have accumulator batteries that will provide greater autonomy and reliability in the event of power outages.

5.1. NETWORK SOLAR POWER PLANT 150 KW

The solar power plant will be used to cover the company's own electricity needs. Schematic diagrams are presented below.

Version without accumulator batteries



The main equipment, materials and works are shown in the table below.

Main equipment and services	PV modules
	Inverter
	Support structures (steel or aluminium profile) for flat roofs
	Cables (DC), connectors, etc.
	SPP construction project (panels, inverters, cables, 0.4kV switchgear of the 0.4kV grid within the building)
Construction, installation and electrical works	Preparatory works, operation of machines and mechanisms
	Installation of structures and modules
	Electrical installation works:
	Cable installation of DC, AC
	Installation of hybrid inverters and protection equipment
	Commissioning works
Other expenses	Transport services
	General and administrative expenses

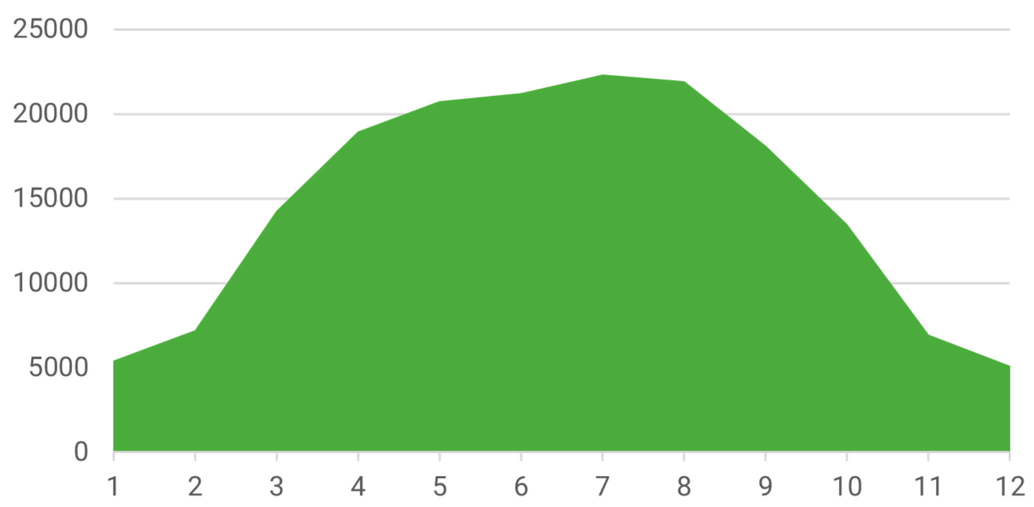
The project implementation period (if there are no delays) is 4-5 months.

The project involves generating electricity from SPPs and replacing grid electricity consumption with this energy. The estimated electricity generation by month is presented below.

Months											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5440,1	7238,1	14276,5	18978,6	20785,4	21266,2	22345,8	21952,2	18115,9	13491,2	6960,8	5110,1

1 - January; **2** - February; **3** - March; **4** - April; **5** - May; **6** - June; **7** - July; **8** - August; **9** -September; **10** - October; **11** - November; **12** - December.

Electricity generation during the year

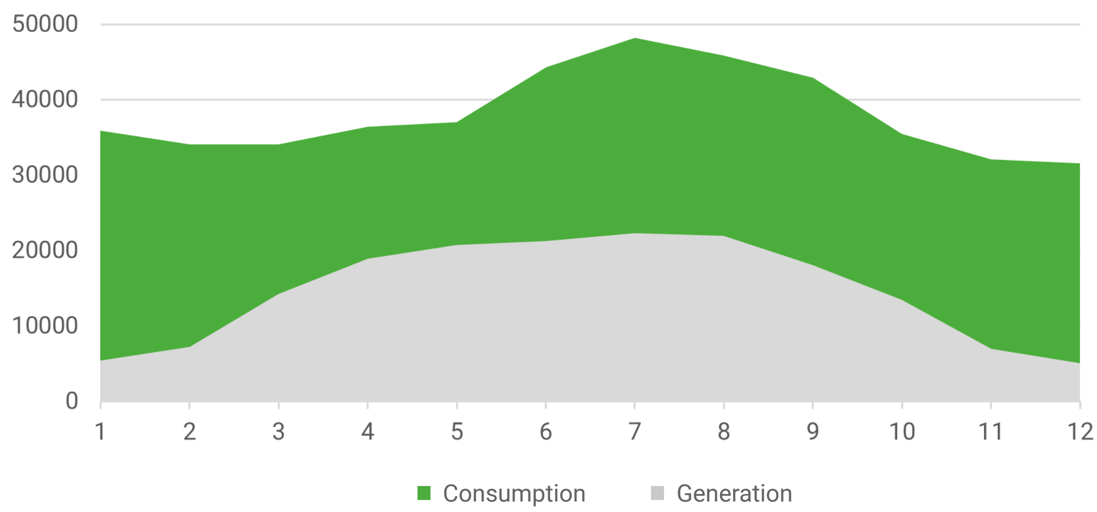


Planned annual generation of 175 960.8 kWh per year [3] :

The total annual consumption (averaged over 2019-2022) of electricity is 458 310.5 kWh, i.e. the plant will provide **38.4% of the electricity consumed.**

The diagram shows the portion of electricity that will be replaced by the energy generated by the SPP.

Distribution of electricity consumption and generation during the year



The project envisages the installation of a 150 kW network SPP. The estimated area for the installation of the station is 1000 m².

When calculating the electricity produced during the life cycle of the SPP, it was assumed that the annual energy production would be reduced by 1% from the previous year due to panel degradation (reduction in the amount of energy produced). The lifetime of the SPP is 20 years, and the degradation of the panels over 20 years will be 20%.

The planned generation for the entire lifetime of the plant is **3 087 871.6 kWh.**

5.1.1. Economic effect for a 150 kW network SPP

The total cost of the project is EUR 155 975.1:

141 795.6 EUR - cost of installation and commissioning of the SPP [4];
14 179.5 EUR - unforeseen expenses, exchange rate fluctuations, etc. (10%).

[3] *The following tool was used to calculate generation:* https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html

[4] *The cost of installing and commissioning a SPP per 1 kWh ranges from USD 800 to USD 1500. In this case, the value of 945.3 EUR kWh was taken.*

The annual cost savings will amount to:

B = S · E

B - annual net savings [EUR/year]
S - electricity saved for the year, amounts to **175 960.9** [kWh/year]
E - energy tariff of 0.17 [EUR/kWh]

B = 175 960.9 kWh/year · 0.17 EUR/kWh = 30 427.4 EUR/year

The simple payback period is:

PB = I / B

I - required investment **155 975.1** [EUR]
B - annual net savings **30 427.4** [EUR/year]
PB - simple payback period [years]

PB = 155 975.1 EUR / 30 427.4 EUR/year = 5.1 years

The payback period of the project is about 5.1 years.

5.1.2. Levelised cost of electricity (LCOE)

To begin with, let's calculate the costs of operating and maintaining a SPP.

The annual OM costs can be estimated as 1.5% of the initial investment annually. In addition, the inverter(s) will need to be replaced every 8-10 years depending on their quality and usage. The PV system is expected to have a lifetime of 20 years, so the inverter(s) will need to be replaced at least twice during this period. For the calculations, we assume a unit cost of inverter replacement (R) of 149.8 EUR per 1 kW of capacity.

OM = I · 1.5% · 20 + 2 · R · P

I - required investment **155 975.1** [EUR]
R - specific cost of inverter replacement 149.8 [EUR/kW]
P - capacity of SPP - 150 [kW]

OM = 155 975.1 EUR · 1,5% · 20 + 2 · 149.8 EUR/kW · 150 kW = 91 752.1 EUR

The levelised cost of electricity (LCOE) is an indicator of the cost of electricity per 1 kWh.

LCOE = (I + OM) / G

I - required investment **155,975.1** [EUR]
OM - costs of operation and maintenance of the SPP **91,752.1** [EUR] (10%)
G - planned generation for the entire lifetime of **606,094.4** [kWh]

LCOE = 0.08 EUR/kW

At the current electricity tariff of 0.17 EUR/kWh, the LCOE is almost 2.2 times lower.

This network SPP will only supply power to the well during the daytime, which will help reduce dependence on the central power supply. However, in the event of a power outage at night or in the evening, additional measures to ensure power supply will be required.

5.1.3. Environmental impact

The project will reduce energy consumption and thus reduce CO_2 emissions. The following coefficients are used to calculate the emission reductions.

Electricity	0.4998 tonnes/MWh

The emission factor is taken from Table 5 of the National and European Emission Factors for Electricity (NEEFE) database (average for 2015-2020).

https://data.jrc.ec.europa.eu/dataset/919df040-0252-4e4e-ad82-c054896e1641

The annual reduction of emissions in CO_2 equivalent will be as follows:

$$CO_2 = S \cdot \kappa$$

S - electricity generated per year, is **175 960.9** [kWh/year]
k - emission conversion factor, according to the table above, is 0.4998 [tonnes/MWh] [5]
CO_2 - reduction of emissions in CO_2 equivalent [tonnes/year]

[5] *Average value for 2015-2020*

CO_2 = 175 960.9 kWh/year / 1000 · 0.4998 tonnes/MWh = 87.9 tonnes/year

The reduction in CO_2-equivalent emissions over the entire lifetime of the plant will be as follows:

CO_2 = 606 094.4 kWh / 1000 · 0,4998 tonnes/MWh = 302.9 tonnes/year

5.1.4. Solution for a 150 kW network SPP project

To provide partial power supply to the artesian wells, we decided to install a network SPP with a total capacity of 150 kW, which will generate 175 960.9 kWh per year.

The network SPP will provide power to artesian wells only during the daytime, which will reduce dependence on the central power supply. However, in the event of a power outage at night or in the evening, additional measures will be required to ensure power supply.

5.2. HYBRID SPP WITH A CAPACITY OF 150 KW

Calculation of batteries for a solar power plant

According to the information provided by the community of Ananiv Water utility of Ananiv City Council, during the previous autumn-winter period, the time of power outage was 4 hours in 4 hours. Therefore, we assume that the average monthly consumption during the cold season is 33 889.5 kWh per month. Hence, we assume that the average daily consumption will be

33 889.5 / 30 = 1 129.7 kWh/day. Based on an assumption based on current observations, the average power outage is 4 hours. Then the required capacity of the batteries to ensure continuous water supply is 1,129.7 - 4 / 24 = 188.3 kWh.

- lithium Battery 48V 416 Ah BMS Eco Battery (G0480416V);
- rated voltage: 48 volts;
- internal losses: 15%;
- depth of discharge: up to 80-95%;
- battery capacity: 416 ampere hours;
- energy reserve: 20 kWh.

Total capacity = Total daily consumption / 0.8 =
188.3 kWh / 0,8 = 235,3 kWh.

Then we count the number:

Number of AB = Total capacity (kWh) / AB energy stored (kWh) = 235.3 / 20 = 11.77 pcs

We round up, so the required capacity is 12 cells.

5.2.1. Hybrid solar power plant 150 kW

We take the capacity of the hybrid SPP to be 150 kW.

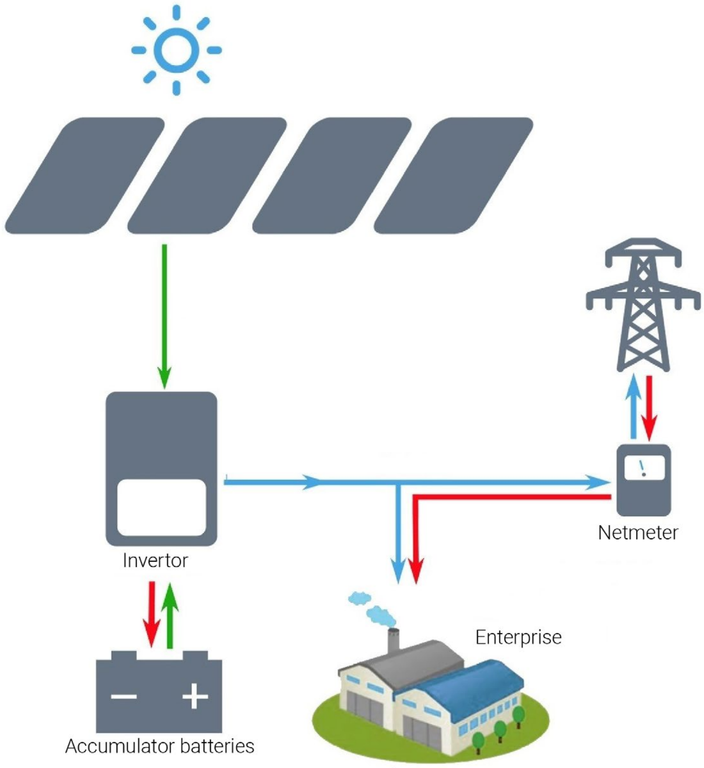
The solar power plant will be used to cover its own electricity needs. Schematic diagrams are presented below in the document.

The main equipment, materials and works are shown in the table below:

Main equipment and services	PV modules
	Inverter (hybrid) Accumulator batteries
	Support structures (steel or aluminium profile) for flat roofs
	Cables (DC), connectors, etc.
	SPP construction project (panels, inverters, cables, 0.4kV switchgear of the 0.4kV grid within the building)
Construction, installation and electrical works	Preparatory works, operation of machines and mechanisms
	Installation of structures and modules
	Electrical installation works:
	Cable installation of DC, AC
	Installation of hybrid inverters and protection equipment
	Commissioning works
Other expenses	Transport services
	General and administrative expenses

The project implementation period (in the absence of delays) is 4-5 months.

Version with accumulator batteries

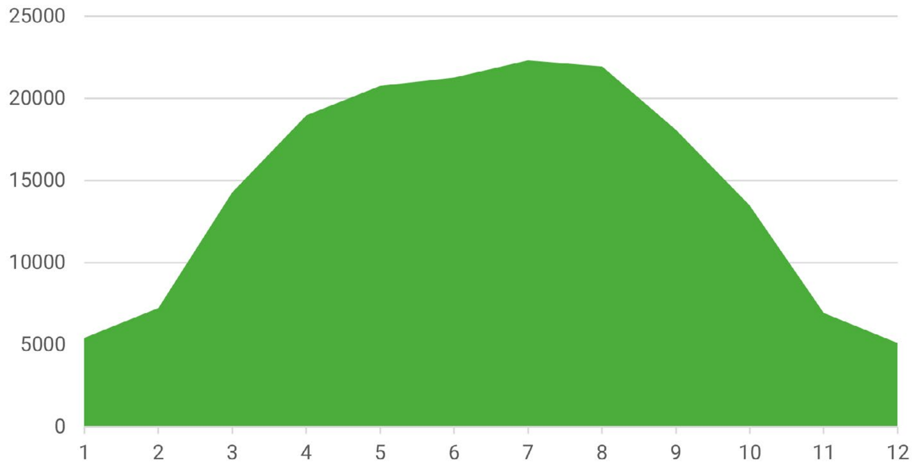


The project involves the generation of electricity by the SPP and the replacement of electricity consumption from the grid with this energy. The estimated electricity generation by month is presented below.

Months											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5440,1	7238,1	14276,5	18978,6	20785,4	21266,2	22345,8	21952,2	18115,9	13491,2	6960,8	5110,1

1 - January; **2** - February; **3** - March; **4** - April; **5** - May; **6** - June; **7** - July; **8** - August; **9** -September; **10** - October; **11** - November; **12** - December.

Electricity generation during the year

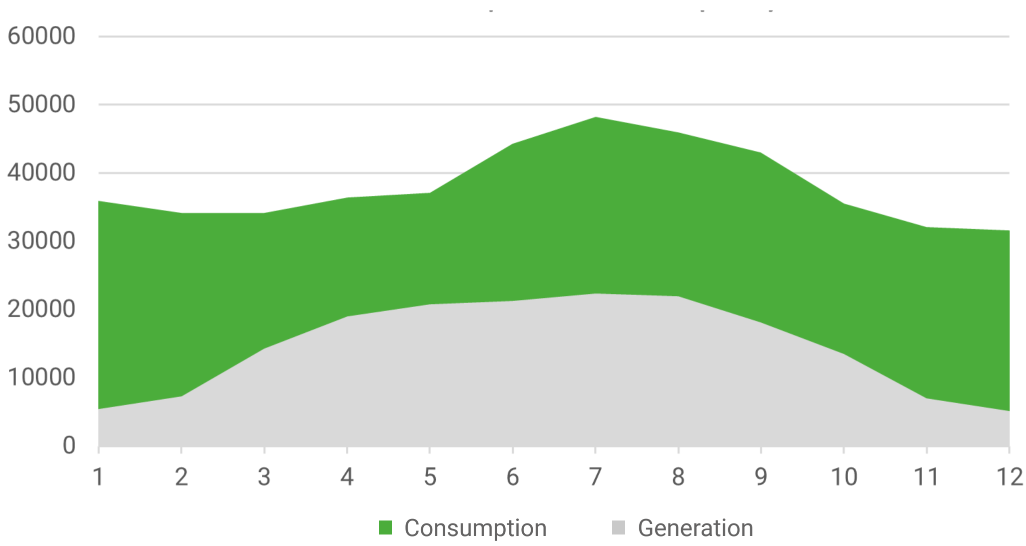


Planned annual generation - 175,960.8 kWh per year [6]:

The total annual consumption (averaged over 2019-2022) of electricity is 458 310.5 kWh, i.e. the plant will provide **38.4% of the electricity consumed.**

The diagram shows the share of electricity that will be replaced by the energy generated by the SPP.

Distribution of electricity consumption and generation during the year



The project envisages the installation of a 150 kW hybrid solar power plant. The estimated area for the installation of the plant is 1000 m².

When calculating the amount of electricity produced during the life cycle of the solar power plant, it was assumed that the annual energy produced would decrease by 1% from the previous year due to panel degradation. The lifetime of the SPP is 20 years, and the degradation of the panels over 20 years will be 20%.

The planned generation for the entire lifetime of the plant is **3 087 871.6** kWh.

5.2.2. Economic effect for a 30 kW hybrid SPP

The total cost of the project is 221 408.6 EUR, of which:

141 795.6 EUR - cost of installation and commissioning of the SPP [7];

14 179.5 EUR - unforeseen expenses, exchange rate fluctuations, etc. (10%);

59 484.9 EUR - cost of batteries [8];

5 948.4 EUR - unforeseen expenses, exchange rate fluctuations, etc. (10%).

[6] *The following tool was used to calculate generation:* https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html

[7] *The cost of installing and commissioning a SPP per 1 kWh ranges from USD 800 to USD 1500, in this case we assume EUR 945.3 kWh.*

[8] *The cost of batteries is assumed to be the market average and amounts to 4957.0 EUR/each.*

The annual cost savings will amount to:

$$B = S \cdot E$$

B - annual net savings [EUR/year]
S - electricity saved for the year, amounting to **175,960.9** [kWh/year]
E - energy tariff of 0.17 [EUR/kWh]

$$B = 175\,960.9 \text{ kWh/year} \cdot 0.17 \text{ EUR/kWh} = 30\,427.4 \text{ EUR/year}$$

The simple payback period is:

$$PB = I / B$$

I - required investment **221 408.6** [EUR]
B - annual net savings **30 427.4** [EUR/year]
PB - simple payback period [years]

$$PB = 221\,408.6 \text{ EUR} / 30\,427.4 \text{ EUR/year} = 7.3 \text{ years}$$

The payback period of the project is about 7.3 years.

5.2.3. Levelised cost of electricity (LCOE)

To begin with, let's calculate the costs of operating and maintaining a SPP. The annual O&M costs can be estimated as 1.5% of the initial investment annually. In addition, it will be necessary to replace the inverter(s) every 8-10 years depending on their quality and usage. The PV system is expected to have a lifetime of 20 years, so the inverter(s) will need to be replaced at least twice during this period. For the calculations, we assume a unit cost of inverter replacement (R) of 149.8 EUR per 1 kW of capacity.

$$OM = I \cdot 1.5\% \cdot 20 + 2 \cdot R \cdot P + AB$$

I - required investment **221 408.6** [EUR]
R - specific cost of inverter replacement **149.8** [EUR/kW]
P - capacity of the SPP 150 [kW]
AB - planned cost of batteries based on their replacement once **59 484.9** [EUR]

OM = 221 408.6 EUR · 1.5% · 20 + 2 · 149.8 EUR/kW · 150 kW + 59 484.9 EUR = 170 867.1 EUR

he levelised cost of electricity (LCOE) is an indicator of the cost of electricity per 1 kWh.

LCOE = (I + OM) / G

I - required investment **221 408.6** [EUR]
OM - operation and maintenance costs **170 867.1** [EUR]
G - planned generation for the entire lifetime of the plant **606 094.4** [kWh]

LCOE = (221 408.6 EUR + 170 867.1 EUR) / 606 094.4kWh = 0.12 EUR/kW

At the current electricity tariff of 0.17 EUR/kWh, the LCOE is 1.4 times lower.

Thus, we can say that a hybrid SPP with batteries is a cost-effective model. Given the current situation in Ukraine and the constant threat of blackouts, the hybrid SPP option will provide a certain reliability of electricity supply for a short period of time.

5.2.4. Environmental impact

The project will reduce energy consumption and thus reduce CO_2 emissions. The following coefficients are used to calculate the emission reductions.

Electricity	**0.4998 tonnes/MWh**

The emission factor is taken from Table 5 of the National and European Emission Factors for Electricity (NEEFE) database (average for 2015-2020).

https://data.jrc.ec.europa.eu/dataset/919df040-0252-4e4e-ad82-c054896e1641

The annual reduction of emissions in CO_2 equivalent will be as follows:

$$CO_2 = S \cdot к$$

S - electricity generated per year, is **175,960.9** [kWh/year]
k - emission conversion factor, according to the table above, is 0.4998 [tonnes/MWh] [9]
CO_2 - reduction of emissions in CO_2 equivalent [tonnes/year]

[9] ***Average value for 2015-2020***

$$CO_2 = 175\,960.9 \text{ kWh/year} / 1000 \cdot 0.4998 \text{ tonnes/MWh} = 87.9 \text{ tonnes/year}$$

The reduction in CO_2-equivalent emissions over the entire lifetime of the plant will be as follows:

$$CO_2 = 606\,094.4 \text{ kWh} / 1000 \cdot 0.4998 \text{ tonnes/MWh} = 302.9 \text{ tonnes/year}$$

5.2.5. Solution for a 150 kW project

To provide partial power supply to artesian wells, it was decided to install a hybrid SPP with a total capacity of 150 kW, which will generate 175 960.9 kWh per year.

The hybrid SPP with batteries will partially reduce dependence on the central power supply and ensure stable power supply to the wells during possible power outages.

APPENDIX 1
(150 kW solar power plant)

European Commission

Performance of grid-connected PV

PVGIS-5 estimates of solar electricity generation:

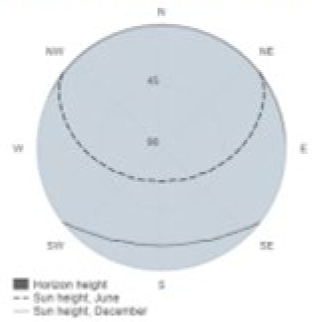
Provided inputs:

Latitude/Longitude:	47.734,29.966
Horizon:	Calculated
Database used:	PVGIS-SARAH2
PV technology:	Crystalline silicon
PV installed:	150 kWp
System loss:	14 %

Simulation outputs

Slope angle:	36 (opt) °
Azimuth angle:	-3 (opt) °
Yearly PV energy production:	175960.78 kWh
Yearly in-plane irradiation:	1490.29 kWh/m²
Year-to-year variability:	8013.47 kWh
Changes in output due to:	
Angle of incidence:	-2.84 %
Spectral effects:	1.26 %
Temperature and low irradiance:	-6.97 %
Total loss:	-21.29 %

Outline of horizon at chosen location:



Monthly energy output from fix-angle PV system:

Monthly in-plane irradiation for fixed-angle:

Monthly PV energy and solar irradiation

Month	E_m	H(i)_m	SD_m
January	5440.1	42.3	1968.3
February	7238.1	56.7	2423.1
March	14276.5	114.6	3060.0
April	18978.6	158.5	2344.8
May	20785.4	179.7	2187.9
June	21266.2	187.1	1125.4
July	22345.8	197.8	1219.4
August	21952.2	194.0	1533.1
September	18115.9	154.0	2394.1
October	13491.2	109.9	2188.4
November	6960.8	55.4	1187.9
December	5110.1	40.4	1794.6

E_m: Average monthly electricity production from the defined system [kWh].

H(i)_m: Average monthly sum of global irradiation per square meter received by the modules of the given system [kWh/m²].

SD_m: Standard deviation of the monthly electricity production due to year-to-year variation [kWh].

Joint Research Centre

Report generated on 2024/07/07