Identifying Photovoltaic Water Pumping (PVWP) Systems Opportunities in Albanian's Agriculture Context.

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Abstract: *A lot of economic analyses have been conducted in the last ten years to establish the most cost-effective solution for irrigation and evaluation of the project profitability. The benefits generated by the PVWP providing water by a submersible pump located inside a deep well have been highlighted for Divjaka region. The solar potential in the site is quite enough to be used to pump water from the deep well into the tank positioned at an effective altitude which can provide the water quantity and pressure by gravity. The study shows that installing a PVWP system represents the best technical and economic solution to drive a water pump that provides water for sprinkler irrigation. The economic benefits have been also addressed, evaluating the energy production and distribution throughout the year and the specific cost per* m^3 *of water supplied (€/*m^3*). Renewables are the key to enhance food and water security, drive agri-food productivity, leading to socio-economic benefits in recovering from post-Covid-19. By combining our knowledge, data collected, surveys together can contribute to economic growth of our community-ensuring access to clean and affordable energy and raising the standard of living of rural and most vulnerable communities. In the area there are used two types of water pumping for irrigation purposes: Diesel driven water pumps and electricity powered water pumps. Both systems are very costly due to the high fuel cost and on the other hand self-investment to bring electricity from the national distribution lines are needed.*
Keywords*: PVWP, PVsyst, RES, Irrigation*

1. Introduction

The development of renewable energy sources as a means of meeting the global energy demand and simultaneously replacing fossil fuels as one of the key drivers of climate change has become one of the major societal challenges of our time. In this context, photovoltaic (PV) systems offer great potential and are considered even more efficient in capturing sunlight energy than photosynthesis [1]. Energy and agri-food systems are deeply connected, and it is needed at every stage of agri-food systems, its current use in their development is unsustainable. On the other hand, about 30% of the world's energy is consumed within agri-food systems, mainly in the form of fossil fuels, and this energy is responsible for a third of their greenhouse gas emissions [2]. Renewable Energy Sources is essential for agri-food systems transformation and development, climate resilience and net-zero strategies by 2030 in Albanian context as the majority of the rural population lies their economy on agriculture. Over 2.5 billion people worldwide rely on agriculture for their livelihoods making the sector a key driver for development. These findings are becoming even more relevant, as water demand for irrigation is expected to increase in prospective future climatic conditions [3-4]. Hence, a properly and well-designed irrigation system addresses uniform water application quantities in a timely manner while minimizing losses and damage to soil and crops as well. The design of a proposed gravity sprinkler irrigation system will smooth water characteristics and application rates in respect to the demand and the right time.

In the other hand physical characteristics of the area to be irrigated must be considered in locating the lines and spacing the sprinklers or emitters, and in selecting the type of mechanized system.

The location of the water supply, capacity, and the source of water will affect the size of the pipelines, irrigation system flow rates, and the size and type of pumping plant to be used. The power unit selected will be determined by the overall pumping requirements and the energy source available. The use of PVWP technology for irrigation is considered an innovative and sustainable solution with the aim to provide cost-effective solution within off grid PV concept. Such systems can promote the use of agriculture land, especially in remote areas of Albania.

The combination of PVWP technology with water saving irrigation techniques and sustainable management of the groundwater resources can lead to several benefits. From the technical point of view this system can offer the improvement of grid reliability and limitation of power outages, protection of critical loads, independence from national grid supply, and increased energy security coupled with a fixed energy cost which is immune to future tariffs and fossil fuel costs increases. This article presents a real application **"*Photo Voltaic Water Pump*"** (PVWP) installed in Divjaka region to provide water for irrigation 2.0 ha.

2. Off - Grid PV systems applications

Solar irrigation, among the most mature applications, is being widely adopted to improve access to water, thus enabling multiple cropping cycles and increasing resilience to changing rainfall patterns. The use of solar irrigation pumps has raised farmers' incomes by 50% or more in India compared to rain-fed irrigation. In Rwanda, smallholder farmers' yields have grown by about a third. The use of solar irrigation also displaces current and future fossil fuel use as the land area under irrigation expands. In so doing, it lowers emissions. Bangladesh's Nationally Determined Contribution under the Paris Agreement, for example, identifies solar irrigation as a key measure to mitigate climate change. Life-cycle emissions for solar-powered water pumping are estimated to be 95% to 98% lower than for pumps powered by grid electricity or diesel fuel [5]. Today, PV is one of the fastest-growing renewable energy technologies and is ready to play a major role in the future global electricity generation mix and a contribution for some 3.8 million jobs, or nearly a third of the sector total [6.]]. Using solar PV to power mini-grids is an excellent way to bring electricity access to people who do not live near power transmission lines, particularly in developing countries with excellent solar energy resources and reducing the negative effect on environmental.

The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form to be replaced and integrated in existing power systems. Solar panels have a lifespan of roughly 30 years and come in variety of shades depending on the type of material used in manufacturing.

Off grid PVWP systems applications have been studied to cover a lot of issues, especially to provide water for drinking purposes in the areas that suffer the lack of electricity. Nevertheless, the drastic fall in prices of PV modules due to the new-born production and costless technologies of the PV lead to increased interest on research and development of off grid PV systems, encouraging greater system flexibility and large-scale integration and new applications especially in Albania. It is also essential to identify economic, technical, and environmental constraints that can negatively affect the 3 operations of PVWP systems.

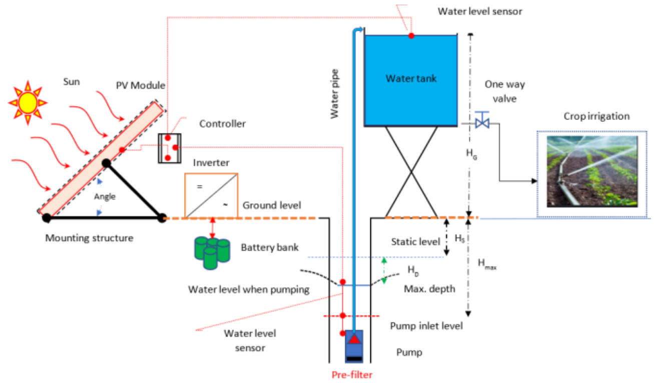

Figure 1: *Integrated proposed PVWP system.*

Both systems can be applied using open or under pressure water tank. The pump can be immersed or on the ground level. The water is pumped into a storage tank, according to sun availability. Pressure (head) is mainly related to the difference between the input and output levels. The pump should at least provide a total head which as a result of several contributions. In PVsyst the ground level served as a reference, hence:

1

where:

H_G=head due to the height of the outlet pipe above the ground (assuming that outlet pressure is negligible).

H_S=static head due to the depth of the water level in the well, in absence of any pumping.

H_D = dynamic "drawdown" head: in a borehole well, the effective water level is dynamically lowered by the water flow extraction

H_F=friction losses in the piping circuit, which depend on the flowrate. Solar PV offers better benefits and reliable solutions for consumers in rural areas who do not have access to the grid [7]. The economic benefit is assessed based on the LCOE which represents a good starting point to compare benefits and competitiveness of different technologies. Photovoltaic systems are cost-effective in small off-grid applications, providing power, to rural homes in developing countries, off-grid cottages and motor homes in industrialised countries, and remote telecommunications, monitoring and control systems worldwide.

The studies have demonstrated that a solar PV combined with diesel engine (hybrid) has relatively lower LCOE than a pure diesel generator-only. The IEA estimates that to achieve the goal of universal electricity access, 70% of the rural areas that currently lack electricity will need to be connected using mini grid or off-grid solutions. Photovoltaic systems can be combined with fossil fuel driven (Genset) motors. Off-grid applications include both stand-alone systems, and hybrid systems, which are similar to stand-alone systems but also include a fossil fuel generator (Genset) to meet some of the load requirements and provide higher reliability. The studies have demonstrated that a solar PV combined with diesel engine (hybrid) has relatively lower LCOE than a pure diesel generator-only. Nevertheless, the capital cost of the battery, which is one of the most significant components in LCOE evaluation aims to be reduced to more than 60% by 2030 [8]

3. Photovoltaic theory and PVWP calculations.

In this paper the off-grid applicability of the PVWP project altering the existing genset/electric water pump options is investigated for irrigation. Thus, an accurate methodology comprehending in-depth analysis of the benefits must be applied and always required. The need for a pile of datas including physical characteristics, financial viability, environmental advantage, carbon credits, social or other self-interests of the project, will help the energy planers to a mature decision. For this work PVsyst model is chosen. The model uses a computerized system with integrated mathematical algorithms and top to bottom approach. It provides a cost technical and economic analysis and also some financial summary. The PVsyst Software has been developed to overcome the barriers to clean energy technology implementation at the preliminary feasibility stage.

First it is analysed the capacity and structure of the actual water demand and then choosing the right PVWP system. For the chosen water demand and pumping water system it is easy to select from the database the most suitable module type and model, respectively matching on recommendations and trends. The water is provided from surveys in the site, from the literature of the field from recommendations and also from the owner declarations.

4. Basics of Solar Energy Theory

Before entering into the details of the PV model, it will be useful to review briefly some basic concepts of solar energy engineering. Many of the variables derived in this section will be used in several parts of the model. For the most part, the equations in this section come from a standard textbook on the subject, Solar Engineering of Thermal Processes, by Duffie and Beckman (1991) [9], to which the researchers can address various technical aspects.

5. Declination

The declination is the angular position of the sun at solar noon, with respect to the plane of the equator. Its value in degrees is given by Cooper's equation:

$$\delta = 23.45\sin\left(2\pi\frac{284+n}{365}\right) \qquad (2)$$

where $\boldsymbol{n}$ is the day of year (i.e. n=1 for January 1, n=32 for February 1, etc.). Declination varies between -23.45° on December 21 and +23.45° on June 21.

6. Solar hour angle and sunset hour angle

The solar hour angle is the angular displacement of the sun east or west of the local meridian, morning negative, afternoon positive. The solar hour angle is equal to zero at solar noon and varies by 15 degrees per hour from solar noon. The sunset hour angle ω_s is the solar hour angle corresponding to the time when the sun sets and given by equation 3:

$$\omega_s = -\tan\psi\tan\delta \qquad (3)$$

ψ represents the latitude of the site specified by the user.

7. Extraterrestrial radiation and clearness index

Solar radiation outside the earth's atmosphere is called extraterrestrial radiation. Daily extraterrestrial radiation on a horizontal surface, H_0, can be computed for day $\boldsymbol{n}$ from the following equation:

$$H_0 = 86400\frac{G_{sc}}{\pi}\left(1+0.33\cos(2\pi\frac{n}{365})\right) \qquad (4)$$

$$(\cos\psi\cos\delta\sin\omega_s + \omega_s\sin\psi\sin\delta)$$

where G_{sc} is the solar constant equal to 1,367 W/m2, and all other variables have the same meaning as explained in equation 1 and 2. Before reaching the surface of the earth, radiation from the sun is attenuated by the atmosphere and the clouds. The ratio of solar radiation at the surface of the earth to extraterrestrial radiation is called the clearness index, defined in equation 4:

$$\overline{K}_T = \frac{\overline{H}}{\overline{H}_0} \qquad (5)$$

where $\overline{H}$ is the monthly average daily solar radiation on a horizontal surface and $\overline{H}_0$ is the monthly average extraterrestrial daily solar radiation on a horizontal surface. $\overline{K}_T$ values depend on the location and the time of year considered; they are usually between 0.3 (for very overcast climates) and 0.8 (for very sunny locations).

8. Calculation of average efficiency

The array is characterized by its average efficiency, η_p, which is a function of average module temperature Ta_c:

$$\eta_p = \eta_r \left[1 - \beta_p (T_c - T_r)\right] \quad (6)$$

where η_r is the PV module efficiency at reference temperature T_r (25°C), and β_p is the temperature coefficient for module efficiency, T_c is related to the mean monthly ambient temperature T_a through Evans' formula (Evans, 1981) [10]:

$$[T_c - T_a] = (219 + 832\overline{K}_t)\frac{NOCT - 20}{800} \quad (7)$$

where NOCT is the Nominal Operating Cell Temperature and K_t the monthly clearness index. η_r, NOCT and β_p depend on the type of PV module considered. Such values can be manually entered into the model, but for "standard" technologies, assumed values are given in Table 1.

Table 1: *PV module characteristics for standard technologies.*

PV module type	η_r *(%)*	*NOCT (°C)*	β_p *(%/°C)*
Mono - Si	13.0	45	0.4
Poly - Si	11.0	45	0.4
a-Si	5.0	50	0.11
CdTe	7.0	46	0.24
CIS	7.5	47	0.46

The equation above is valid when the array's tilt is optimal (i.e. equal to the latitude minus the declination). If the angle differs from the optimum the right side of equation (8) has to be multiplied by a correction factor Cf defined by:

$$C_f = 1 - 1.17 \times 10^{-4} (s_m - s)^2 \quad (8)$$

where s_M is the optimum tilt angle and **s** is the actual tilt angle, both expressed in degrees.

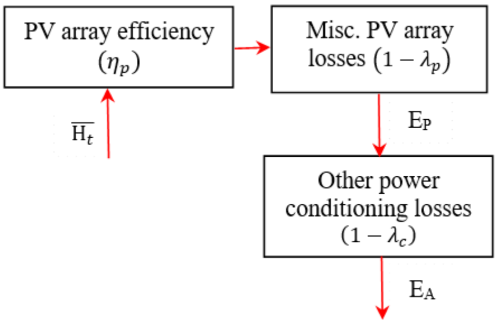

Figure 2: *Flowchart for PV Array Model*

9. Other corrections

The energy delivered by the PV array, E_P, is simply:

$$E_P = S \cdot \eta_p \cdot \overline{H}_t \quad (9)$$

where S is the area of the array. It has to be reduced by "miscellaneous PV array losses" λ_p and "other power conditioning losses" λ_c.

$$E_A = E_P(1-\lambda_p)(1-\lambda_c) \quad (10)$$

where E_A is the array energy available to the load and the battery. The overall array efficiency η_A is defined as:

$$\eta_A = \frac{E_A}{S \cdot \overline{H}_t} \quad (11)$$

10. Off-Grid Model

Off-grid renewable power can come from a variety of sources, ranging from large-isolated power grids to solar lights and solar home systems. In addition to households, off-grid renewables provide power for water pumping, street lighting, telecommunications towers, rural schools and clinics, as well as for remote commercial and industrial facilities and other uses [11].

The off-grid model represents stand-alone systems with a battery backup, with or without an additional genset. The conceptual framework of the model is shown in Figure 3. Energy from the PV array is either used directly by the load or goes through the battery before being delivered to the load. The remainder of the load is provided by the genset if there is one, that is, stand-alone and hybrid systems differ only by the presence of a genset that supplies the part of the load not met directly or indirectly by photovoltaics.

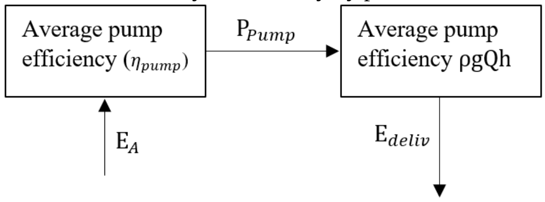

Figure 3: *Energy transformation workflow.*

The water pumping model is based on the simple equations found in Royer et al. (1998) [12] shown schematically in Figure 16. The daily hydraulic energy demand E_{hydr}, in J, corresponding to lifting water to a height h (m) with a daily volume Q (m^3/d) is:

$$E_{hydr} = 86400\rho g Q h(1 + \eta_f) \quad (12)$$

where g is the acceleration of gravity (9.81 m s^{-2}), ρ the density of water (1000 kg/m^{-3}), and η_f is a factor accounting for friction losses in the piping. This hydraulic energy translates into an electrical energy requirement E_{pump}.

$$E_{pump} = \frac{E_{hydr}}{\eta_{pump}} \quad (13)$$

where η_{pump} is the pump system efficiency. If the pump is AC, this equation has to be modified to take into account the inverter efficiency η_{inv}:

$$E_{pump} = \frac{E_{hydr}}{\eta_{pump} \cdot \eta_{inv}} \quad (14)$$

Energy delivered is simply:

$$E_{deliv} = \eta_{pump} \min(E_{pump}, E_A) \quad (15)$$

where EA is the energy available from the array (this quantity should be multiplied by ηinv in the case of an AC pump), and daily water delivered is obtained from:

$$Q_{deliv} = \frac{E_{deliv}}{86400\,\rho g Q h\,(1+\eta_f)} \quad (16)$$

Suggested array size is calculated simply by inverting the above equations and is therefore equal to E_{pump}/η_A where η_A is the overall array efficiency (see equation 10). This quantity is calculated on a monthly basis and the maximum over the season of use is the suggested array dimension. In the case of an AC pump, suggested inverter capacity is simply taken equal to the nominal array power. This is the only method possible since it is assumed that the pump power rating is not known (only the energy demand is known)

11. PVWP system in PVsyst environment

The selection of the PV must meet different criteria simultaneously:

- generate high quality electricity according to specific standards.
- withstand the high variability of solar radiation characteristics.
- require less maintenance interventions and costless.
- compete economically with other energy sources.
- fast and cost-effective compliance.
- Guarantee the water demand in time and reducing the unused energy level.

From the PVsyst database and technical information obtained from the manufacturer, comparisons were executed to determine the most efficient PV module among five alternative types taken in this study.

After creating the data file in the PVsyst for the selected area the first step is to define the orientation of the solar plane. The quick optimization of the solar energy should be accordingly with respect to function and aim of the proposed PV system. As our system will be used to provide water for irrigation purposes in summer period and for the fixed titled plane type the maximums fall in the 23^o titled angle and azimuth 0^o. For the summer period (April to September) the transposition factor resulted 1.06, loss in respect to optimum is -0.2% and global yield (in summer) on collector results 1307kWh/m^2 (see table nr 2).

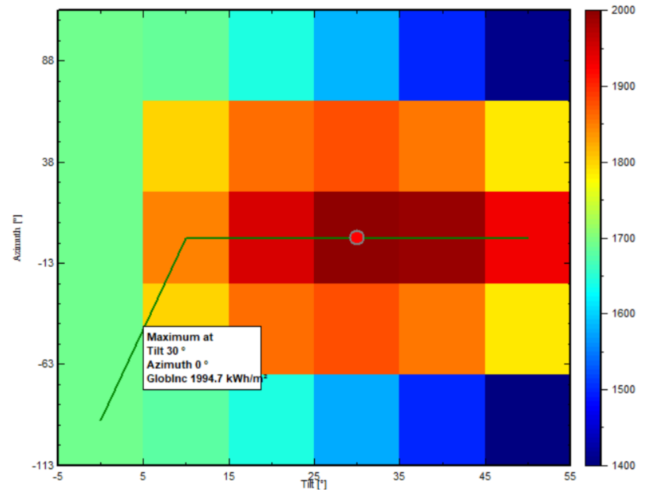

Figure 4: *Optimization tilt and azimuth angle at the proposed PVWP system.*

PVsyst enable the users to perform automatically a set of simulations, where one or more parameters are varied systematically according to a specified range. Optimization tools of the 'Orientation' suggest a tilt angle of 30^o and azimuth0^o. In our calculation the tilt angle is suggested 23^o up 30^o. But in our case is approximated to 23^o as the aim is to provide water during summer period global yield on collector is 1309 kWh/m^2 while for 30^o is 1294kWh/m^2.

Table 2: *The preliminary parameters chosen for the PVWP* model.

Transposition factor	Loss in respect to optimum (%)	Global yield (in summer) on collector (kWh/m^2)
1.06	-0.2%	1307

In the second step it is obligatory to define the "Water needs" button selecting "Pumping Hydraulic Circuit" and one can choose among one of the three available systems (refer figure 4):

1. Pumping from a deep well, to a tank storage,
2. Pumping from a lake or river, to a tank storage,
3. Pumping into a pressurized tank, for water distribution.

In our case study pumping from a deep well to a tank storage is defined. The well can be 5 meters up to 15 meters deep. From the farmers statement, normally 10 meters deep well can guarantee the water demand referring the driest month (July) for more 10 hours for irrigation of carrots or potatoes. The actual well is around 15 meter and the water amount is able to provide 8 hours irrigation per day and the specific drawdown of -0.08m/m^3/h with a maximum flowrate of 62.5m^3/h, dynamic lower level -10m, the tank volume is defined 200m^3 which can easily provide the water amount per each irrigation day with a reserve of 40%. Feeding altitude is selected 6.5m above ground level calculated as a result of the water parameters needed at the end of the circuit line.

Table 3: *Main parameters from a deep well to a tank storage.*

	Unit	Value
Static level	m	-5
Specific drawdown	m/m^{3}h	-0.08
Maximum flowrate	m^3/h	62.5
Lower dynamic level	m	-10
Hydraulic circuit	m	250
Number of elbows	pieces	30
Other friction losses	%	3-10
Tank volume	m^3	200
Tank diameter	m	6.5
Water full height	m	6.03
Feeding altitude	m	6.5
Pipe	"	4

The tank diameter volume is defined taking into account the daily water quantity demand referring the worst case (the most dry month of the year results July), crop type and soil type. The references for the water needs profile are provided form the literature given below in figure 5. Sprinkler irrigation systems are well adapted to carrot and potatoes irrigation. In the region, sprinkler designs of 12x12 m were common in carrot irrigation. Sprinkler flow rates varies from 0.3-4m^3/h. Similar result, 2.57 m^3/h sprinkler having flow rate at 2.38 atm pressure with 4.5/4.8 mm nozzle diameter was also mentioned elsewhere [13] in same region. Durations for using sprinklers with 0.3-1.0 m^3/h and 1.5-2.5 m^3/h flow rates were 9-10 h and 5-6 h. Yield or quality of carrot root is highly affected by carrot cultivar, fertilizer management, cultural practices in vegetation period and correct selection or management of irrigation system. In our study, carrot root yield was in the range between 60 and 85 m^3/ha. Irrigation water was obtained from the ground water source in research region. Average electricity consumption for pumping unit volume of water and seasonal electricity consumption were determined as about 0.305 kwh/m^3 and 5338 kwh/ha (17500x0.305), respectively. In research of, energy consumption of such pump was about 0.340 TL/kwh. It was calculated as 1815 TL/ha or $485/ha. In generally water requirement for vegetable crop can be calculated by using the following formula [14]:

$$W_{req} = \frac{A * PE * P_C * K_C * w_a}{E_u} \qquad a$$

Where: W_{req}=Peak water requirement (m^3/day); A=crop area (20 000m^2); PE =Pan Evaporation rate (mm/day) converted to m/day; (8-10 mm/day); Pc=Pan Coefficient (0.7 to 0.9); Kc=Crop Coefficient (0.8 to 1); wa=wetted area (%) taken (90% for sprinkler irrigation); Eu=Emission uniformity of sprinkler irrigation (0.8).

By substituting the mentioned above values, the water requirement is approximately 137.7 m^3/day

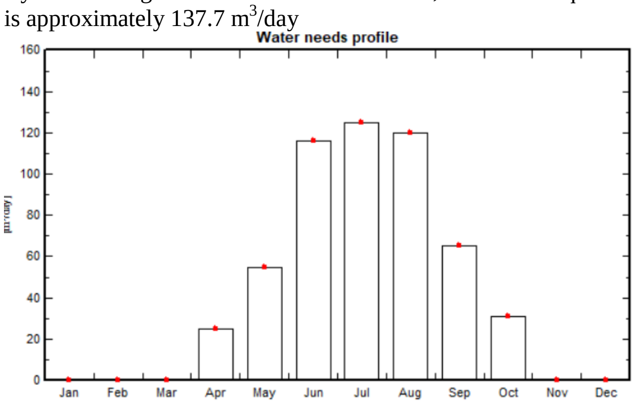

Figure 5: *Water demand profile for the proposed case study.*

As it can be seen from the water needs profile given in figure 5 the average yearly water demand is around 45 m^3/d or 16 334 m^3 for the whole year for the given surface in figure number 1.

The next step is select the most suitable water pump based on the water needs profile. This selection should take into the consideration the well type, control type and solar radiation potential as well. The simulation should be performed to provide the best solution in terms of specific energy, system and pump efficiency and reducing fraction of unused energy produced by the PV system. The result from the simulation carried out are summarized in table 4.

Table 4: *Main technical parameters of the water pump*

Centrifugal Multistage (Grundfos SOF 9-3 v30-300V)			
Maximal power	1400 W		
Voltage	170 V		
Max.Current	8.2 A		
Head min/Nom/Max (meterW)	5	15	25
Corresp.Flowrate	17	14.4	11.0
Corresp. Power	1400	1400	1400
Efficiency	16.6	41.9	53.7

Table 5: *Main technical parameters of the PV module used in the study*

	Technology	*Specification*
PV System	Generic/Si-poly	285Wp 30V
Sizing voltages		Vmpp (60°C) 31.2V
		Voc (-10°C) 49.9 V
Modules in series		3
	Operating conditions	
Vmpp	(60°C)	94V
Vmpp	(20°C)	111V
Voc		150 V
	Plane irradiance 1000 kWh/m²	
Impp	7.9A	
Isc/Isc (STC)	8.4A/8.4A	
Maximum operating power at 1000 W/m² and 50°C	0.8kW	
Array nominal power (STC)	0.9kW	

Inverter type for this case study is provided from the model universal controller 1000W and suggested control type MPPT - DC converter.

12. Results and analysis

From the simulation of the proposed PVWP system the final results for the efficiency of the system and other techno economic features.

In figure 6 it is given the flowrate as a function of available energy delivered at the pump. At the maximum head of 25m flowrate reaches the level of **11.0 m³/h**

The pump results DC motor and the maximum flowrate is 17 m³/h but in nominal condition the water flowrate then can be pumped is 14.4 m³/h. The water needs can be provided if the pump works 6-8 hour per day then 115m³/day can be discharged into the tank. That is the water demand that system can be provided in one day referring the worst case (July period).

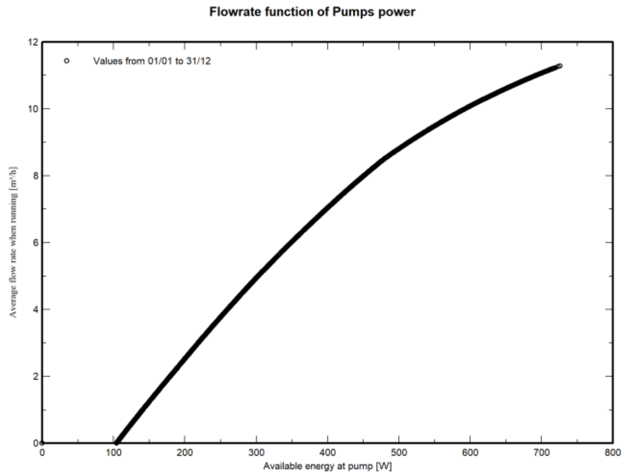

Figure 6: *Flowrate function of pumps power.*

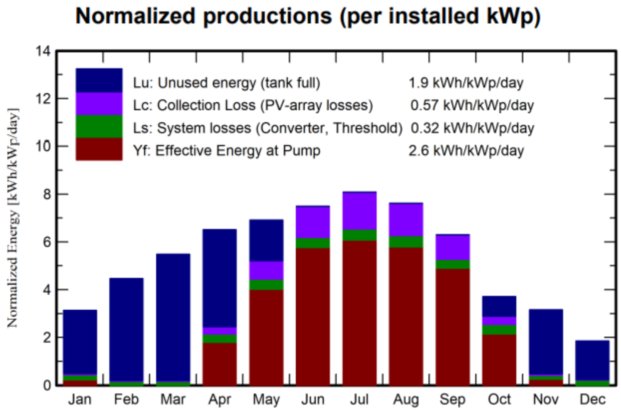

Figure 7: *Normalized Energy (kWh/kWp/day).*

In figure 7 the normalized production (kWh/kWp/day) per each month is given. The maximim production fall in July while in March the unused energy happen due to the zero water demand profile. In January up to May the faction of unsused energy prevails. In summer period from April to October the unused fraction becomes zero as the water demand is higher. The collection losses (PV-array losses) are higher during the summer period reaching the maximum value in July (0.57kWh/kWp/day).
Conveter losses are in the range of 0.32 (kWh/kWp/day).

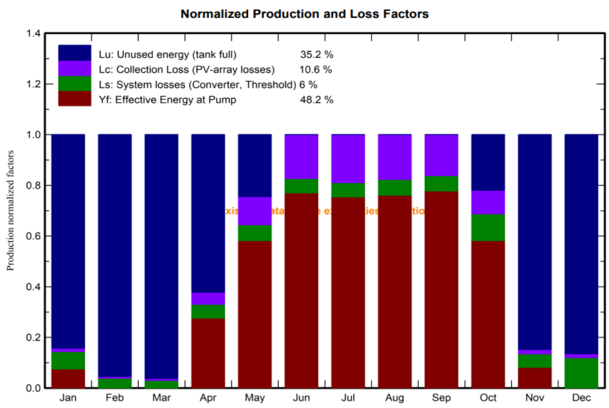

Figure 8: *Normalized Production and Loss Factors.*

In figure 8 the unused energy fraction results 35.2 % due to the water profile demand during winter season. PV array losses are 10.6% while effective Energy at pump results 48.2%.

***Table 7:** Main balances and results from the simulation of the selected PVWP system.*

	GlobEff kWh/m²	EArrMPP kWh	E_PmpOp kWh	ETkFull kWh	H_Pump meterW	WPumped m³	W_Used m³	W_Miss m³	EArray kWh	PR ratio
January	94.0	76.6	6.3	61.0	11.43	100	0	0	76.6	0.076
February	121.5	97.1	0.0	88.3	0.00	0	0	0	97.0	1.000
March	164.9	128.9	0.0	118.5	0.00	0	0	0	128.9	1.000
April	190.1	144.6	46.1	85.8	11.52	741	750	0	144.5	0.276
May	209.2	156.1	106.6	36.4	11.61	1698	1705	0	156.0	0.582
June	219.2	159.0	148.0	0.0	11.63	2394	2571	909	158.9	0.770
July	244.1	173.5	161.4	0.0	11.67	2649	2657	1218	173.5	0.754
August	230.1	166.2	153.6	0.0	11.70	2537	2537	1183	165.9	0.761
September	184.0	135.4	125.7	0.0	11.63	2074	1931	19	135.4	0.778
October	111.7	86.2	57.2	17.8	11.47	907	961	0	86.1	0.582
November	91.8	73.2	6.6	58.8	11.64	111	0	0	73.1	0.082
December	55.5	45.0	0.0	36.7	0.00	0	0	0	44.9	1.000
Year	1916.2	1441.8	811.6	503.5	11.62	13211	13111	3330	1440.8	0.482

Legends

GlobEff	Effective Global, corr. for IAM and shadings	WPumped	Water volume pumped
EArrMPP	Array virtual energy at MPP	W_Used	Water drawn by the user
E_PmpOp	Pump operating energy	W_Miss	Missing water
ETkFull	Unused energy (tank full)	EArray	Effective energy at the output of the array
H_Pump	Average total Head at pump	PR	Performance Ratio

In table 7 Balances and main results per each month of the year are given. The water used throughout the year results 13111 m^3 while the missing water results 3330 m^3. Having in mind that system suggested to incorporate a water tank with 125 m^3 which is taken 200 m^3 providing a reserve of 30% more then the water needs. Other important outputs are carried out for evaluation in the case if the system changes (water pump or well type).

13. Conclusion

The present paper address various aspects related to PVWP energy systems for irrigation purposes in agriculture sector in Divjaka district. Nowadays, benefits coming from the PVWP system is becoming extremely beneficial from both technical and cost point of view and of course environmentally friendly. The perspective of a wide use of green power especially in agriculture sector motivates the policy makers in Albania to evaluate the possibility of funding the proposed systems.

The simulation from the study shows that for 2.0 ha, referring to the chosen PVWP system, the energy at pump becomes 812 kWh, specific energy 0.06kWh/m^3, system efficiency 56.3%, pump efficiency 52.2% while the unused energy fraction results 34.9% (503kWh). The missing water rate is evaluated at a range of 19.6% which is covered by the extra dimension of the water tank.

The study shows very good results compared to the existing water pump systems (totally based on fossil or electricity from the grid) applied for irrigation purposes in Albania. Further investment in RES is essential for agri-food systems transformation and development, climate resilience and net-zero strategies by 2030 in Albanian context, as the majority of the rural population lies their economy on agriculture. The use of this kind of system could have an important contribution in the diversification of energy sources, mitigation of GHG, social and economic development of our country.

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