An overview of agriculture sector in terms of fuel type and systems used for irrigation purposes. Case study: Divjaka region, Albania

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Abstract: *In locations where electricity is not available and distribution lines are far away from the connection point, than other means are necessary to provide water for different applications especially in agriculture sector. Using a diesel pump to deliver water account economic and environmental problems. Fuel prices affect the overall costs of diesel-powered water pumping system thereby reducing the incomes from the sale of vegetables or other planted crops. In addition, the use of a diesel-powered water pump system can lead to considerable amount of CO_2 released to the surrounding which cause global warming. A possible solution to these problems is using renewable energy source like solar power, which is environmentally friendly and available for free. This paper focus on the identification of sector energy consumption and the possibility of application of PVWP system in the agriculture sector. Several economic analyses have been conducted to establish the best cost-effective solution for irrigation in agriculture sector. The possible benefits generated by the PVWP system implementation for the selected region should be highlighted, as well as the effects of the most sensitive parameters. The solar potential in the site showed that PVWP can be the best solution to provide water for irrigation compared to other traditional water pumping technologies and also can reduce the dependency from fossil fuel powered water pumps and can help the diversification of the agriculture sector especially.*

***Keywords**: PV-PUMP STATION, CO_2, GHG, RETScreen Expert.*

1. Introduction

Public interest in the issue of irrigation water pricing has increased worldwide in recent years, with increasing awareness of water scarcity and greater appreciation of the opportunity costs of allocating water among competing uses. Many of the world's large-scale irrigation projects were constructed and placed in service in an era when water was relatively abundant or when the cost of developing water supplies in arid regions seemed a reasonable expense for expanding agricultural production and generating economic growth. Over the years, the incremental costs and benefits of irrigation have changed, as have public preferences regarding the allocation of water among agricultural, municipal, and environmental uses. 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. The integration of distributed renewable energy in agriculture sector can bring a lot of economic benefits to the farmers including the reduction of specific energy use and also can help to the mitigation of GHG emissions. 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 Divjake.

After II WW following the increase in agricultural potential, the region gained significant importance in the economy of the country. This paper assesses the possibility of installing PVWP system at site including an existing greenhouse. The RETScreen software and PVsyst is used for the feasibility and financial viability evaluation. The study found out that the Divjaka municipality part of the Fier county has the highest solar irradiation in Albania, recorded 4.56 kWh/m^2/day. The financial indicators like the internal rate return (IRR), equity payback years, cumulative cash flows and simple profitability index all indicated that the agriculture sector is the best option for the development of solar energy. The impact of the development of these plants will also have a considerable impact on the environment since the research on the field shows a great potential in the reduction in the emission of greenhouse gases (GHG), in some cases around 93%. Such systems are foreseen to play a key role in a stable, costless and emission-less way especially in off-grid concept applications. The performance, availability, costs and carbon intensity of photovoltaic power all indicate that this technology can make a very substantial contribution to reduce carbon emissions and gain carbon credits.

Similarly, in the study of [1] it is shown that Off-grid PV concept applied in telecommunication sector can bring a lot of benefits, especially in the very remote areas. Hence, PVWP systems can be used in the agriculture sector for irrigation purposes.

In the other hand the depletion of fossil fuel and the negative effect on the environment as well as the potential techno-economic merits of "*hybrid combinations*" identified as a good solution moving towards reliable and more feasible energy systems based on renewables [2]. As the need for clean, sustainable energy increases, and renewable technologies get ever more advanced, more projects had been developed in greater sizes and complexities, including on-grid and off-grid solutions based on RES.

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 [3].

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 depending on the type of material used in manufacturing.

2. Site background and installation of proposed PV-Water pump station

In our case study the installation place will be located in Divjaka (41°02'158"N and 19°53'26"E) as it is shown in figure 1. The area has an altitude of 90 m above sea level and the measured average annual air temperature results 15.24°C. Atmospheric mean pressure value and wind velocity measured at 10m altitude results 97.38kPa and 1.1 ms^{-1}.

***Figure 1:** The property of the proposed PVWP location*

The property area chosen for this case study is around 2.0 ha and has an existing water well of 15 m deep (circle in blue). Thanks to the water sources available, the water quantity is provided from the well is enough to irrigate that surface for 8-10 hours per day with no missing water identified.

The property has a modern greenhouse with net surface of 0.5 ha usually used for different crops such as potatoes, tomatoes, and carrots. Daily water amount for irrigation depends on weather condition and temperature. The mean earth temperature varies from 5.6°C in January up to 25.26°C in August while precipitation varies from 25.73mm in July up to 118.5mm in November.

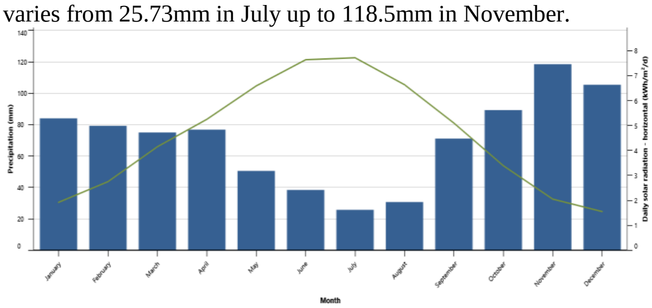

***Figure 2:** The proposed PVWP location daily solar radiation kWh/m^2/day.*

Actually, the owner of the farm uses two different pumps supplied from two different energy sources: Electricity and diesel pump.

The technical parameters and the specific consumption are provided from the owner's monthly bill.

From the model and data provided from Albanian Meteorological Institute it is shown that this region has a high solar potential.

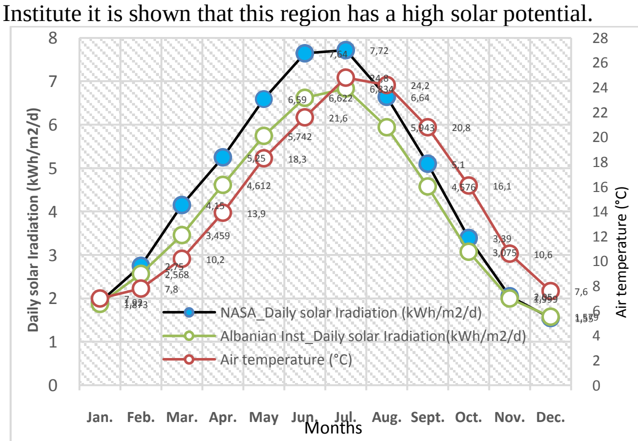

***Figure 3:** Daily solar radiation kWh/m^2/day at the proposed location.*

The main two problems discussed are: the connection point with the national electricity distribution grid and the process towards a cleaner and safer environment as the main fuel type (73%) is provided from fossil powered water pumps is considered in this work. From [4] and its Earth Science research program has long supported satellite systems providing important weather data capable to be fully integrated in RETScreen model. These data include long-term climatologically averaged estimates of meteorological quantities and surface solar energy fluxes. These satellite and model-based products have been shown to be accurate enough to provide reliable solar and meteorological resource data over regions where surface measurements are sparse or non-existent. The highest values are observed during the summer season of the year, while the lowest values are observed in the winter months. The highest solar radiation value 6.834 kWh/m^2/d is reached in July, while the lowest value 1.55 kWh/m^2/d hits in December. According to Albanian Institute of Geo-Sciences, Energy, Water and Environment the annual mean solar radiation and temperature for Divjaka region is 4.082 while referring to NASA and 4.56 kWh/m²/d (11% lower).

***Table 1:** The site-specific solar energy data. Divjaka region. [Solar database and PV software©2022 Solargis]*

Specific photovoltaic power output	*PV_{OUT} specific*	*1554.8*	*kWh/kWp*
Direct normal irradiation	DNI	1725.2	kWh/m^2
Global horizontal irradiation	GHI	1640.9	kWh/m^2
Diffuse horizontal irradiation	DIF	620	kWh/m^2
Global titled irradiation at optimum angle	GTI opta	1912.5	kWh/m^2
Optimum tilt of PV modules	OPTA	34/180	°
Air temperature	TEMP	17.4	°C
Terrain Elevation	ELE	80	m

From Global Solar Atlas, energy planers can generate suitable site information for preliminary studies in EU-28 countries as they consider default values for many factors that are important for a design of a photovoltaic system. For more professional and detailed estimation it is used PVsyst tool that allow configuration of the proposed projects using more detailed solar and weather data as primary inputs to the simulation.

3. An overview of the Albanian Energy system.

3.1 Agriculture sector

Under the pressure of an increased awareness related to environmental issues and costs from the existing energy system in Albania, technological progress and the liberalization of the energy market, in the last 15 years lead to development of wind and solar exploitation technologies in Albania [5]. Renewable energy sources, including solar, wind, hydro, biofuels and other future renewable sources are at the centre of the transition towards a less carbon-intensive and more sustainable energy system. [6].

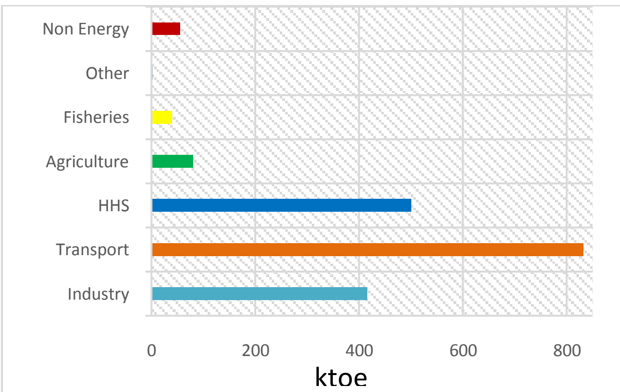

***Figure 4:** Final Energy Consumption by Sectors (ktoe) in Albania*

2018 [5].

As it can be seen in figure 4 the final energy consumption in agriculture sector is around 80.32 ktoe. Transport sector and household are the main two sectors accounting 64% of the total final energy consumption in the country.

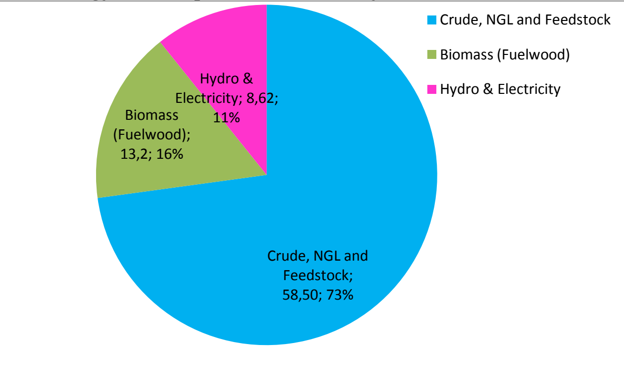

Figure 5: *Agriculture Energy Consumption by fuel type, 2018.[5]*

In figure 5 the consumption by fuel type in agriculture sector is given. The fossil fuel type account for 73% of the final energy consumption in agriculture sector, while electricity and biomass occupy the rest. The reduction of fossil fuel and electricity consumption within agriculture sector is the main focus of this research work.

4. Renewable energy strategy and progress

4.1 Solar energy

The Paris Agreement sets a goal to limit the increase in global average temperature to well below 2°C above pre-industrial levels and to attempt to limit the increase to 1.5°C. Implicit in these goals is the need for a transition to a low-carbon energy sector, which accounts for two-thirds of global emissions. RES, coupled with energy efficiency gains, can provide 90% of the CO_2 emissions reductions in the roadmap to 2050. Renewable energy is therefore a key component of Nationally Determined Contributions (NDCs)–the central implementation tool for countries under the Paris Agreement. At present, the level of detail contained in NDCs differs from country to country, with little in-depth analysis and limited quantitative information about the role of renewable energy in meeting greenhouse gas (GHG) emission reduction targets [7]. Based on the targets projected in global level Albania is making efforts to reduce the rate of electricity import and improve its security of supply fully in line with "Paris Agreement" requirements. The Albanian ministry of Energy and Transportation and its dependency institutions has compiled the ***"The National Energy Strategy 2018-2030"***, consisting on 6 possible scenarios of energy's transition process toward a sustainable and reliable energy by shifting Albania to decentralized renewable energy market, and energy efficiency. This strategy requires reaching a RES share of 42% to the total energy consumption and also reducing CO_2 (referring 2016) level up to 11.5% by the end of 2030. The first goal can be achieved by large scale integration of RES capacities, especially wind generation capacities [8]. The second national energy goal, compared to the baseline scenario in 2016, should be also fully in line with EU objectives, its commitment is to reach a reduction of 11.5% of CO_2 emissions by the end of 2030. The RES share in global electricity generation reached almost 27% in 2019, renewable power as a whole still needs to expand significantly to meet the SDS share of almost half of generation by 2030 which requires the rate of annual capacity additions to accelerate the process [9].

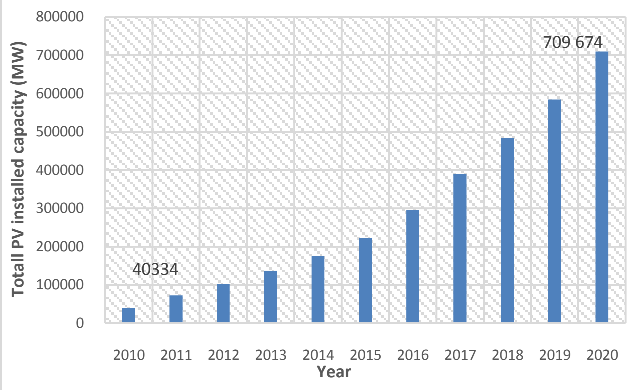

Figure 6: *The global installed capacity trends of the PV systems.*

In the graph in figure 6 the global installed PV capacity is given. The growth of PV capacity worldwide tends an exponential progress and results 18 times more in 2020 compared to 2010. Considerable interest in RES and significant increases in cost of imported oil and very frequent services of related power generation technologies have compelled various countries to search for low-cost energy sources and improved technologies based on RES, PV and synergies between systems to achieve lower cost of electricity generation. Also, limiting the global average temperature rise to 1.5°C will require all sectors of the economy with increasing need for energy to reach zero carbon dioxide (CO_2) emissions early in the second half of this century. Photovoltaics (PV) is a key technology option for realising a decarbonised power sector and sustainable energy supply [10]. Most of those options rely on renewable necessarily supported from energy storage systems (ESS) [11].

5. Off – Grid PV systems applications

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. The research is mainly focused on system design, optimization of system components (such as BOS and solar array performance), and technical and economic comparisons between PV and other traditional stand-alone fossil powered sources. There is a lack of compatibility or similarity between two or more facts including the systematic optimization of energy systems, having in mind the irrigation water requirement (IWR), water resource availability, and crop yield under different water supply conditions. System failures and corresponding economic losses still occur due to the inadequacy of system integration with the environment. In most works done so far, PVWP systems have been considered as independent electricity stations without taking into consideration how the system is affected by the environment (e.g., IWR and water resources). Thus, the first two research questions are: how does the variation in Irrigation Water Requirement (IWR) during the irrigation season affect PVWP systems design and effectiveness (used and unused solar fraction)? and how can the proposed PVWP systems be optimized from an integrated system perspective (taking into consideration water resources in the site)? It is also essential to identify the technical, economic and environmental constraints that can affect the 3 different types of PVWP systems.

1. Deep well to storage.
2. Lake or River to storage.
3. Pressurization

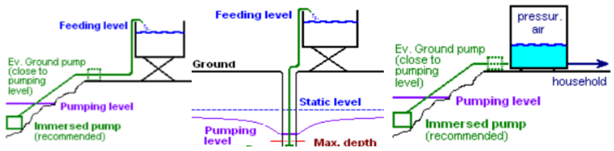

Figure 7: *(a)deep well to storage; (b) Lake or River to storage and (c) Pressurization (source PVSyst)*

Such systems can be applied using open or under pressure water tank. The pump can be immersed or can be positioning on the ground level involving in some cases the need for a boost pump.

6. Economic aspects of PV systems

Three key factors are essential when designing wind power plants. First there must be a sufficient source of solar potential in the proposed region, the PV technology must be promising as well as cost effective. Studies has shown that it is cost-effective for small loads (<10 kWp) need lower capital costs than grid extension and have lower O&M costs than gensets and primary batteries [12]. This section deals with the economic aspects of building a PVWP system with daily water consumption.

Any factor that leads to lower total lifecycle costs, or that yields greater kWh over the chosen analysis period, lowers the LCOE of a PV system. The total lifecycle cost in the numerator is a function of the initial capital cost (which primarily includes the module, the installation hardware and labour, and transaction costs for system installers and financers), as well as ongoing operation and maintenance expenses (which oftentimes includes inverter replacement) and decommissioning costs including module collection and recycling. The total lifecycle energy production (the kWh in the denominator) is a function of location as well as module and system reliability and performance [12].

The global weighted-average LCOE of utility-scale PV plants declined by 82% between 2010 and 2019, from around \$0.378/kWh to \$0.068/kWh in 2019, with a 13% reduction year-on-year in 2019. At an individual country level, the weighted average LCOE of utility-scale solar PV declined by between 66% and 85% between 2010 and 2019.

7. PV Project Costs

Although the cost of PV panels energy has dropped dramatically in the last 10 years, technology requires a higher initial investment than traditional fossil fuel generators. Approximately 55% of the cost goes to module, 15% to inverter and the rest is belongs to BoS and installation costs (see graph in figure 8).

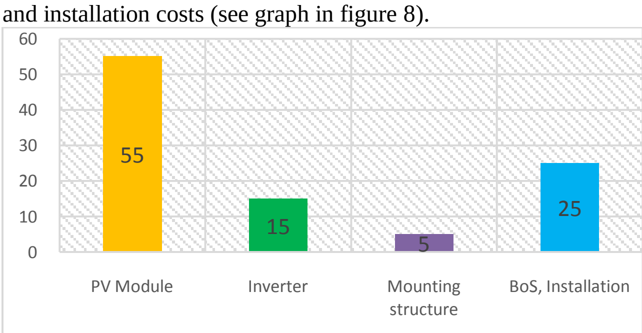

Figure 8: Cost breakdown of PV system components (%) [1]

8. Capital Investment Cost

With very rapid reductions in solar PV module and balance of system costs, utility-scale solar PV is now increasingly competing head-to-head with alternatives and without financial support. Lower solar PV module prices and ongoing reductions in balance of system costs remain the main driver of reductions in the cost of electricity from solar PV. The costs for renewable energy technologies reached new lows again last year. Solar and wind power have emerged as the most affordable power source for many locations and markets, with cost reductions set to continue into the next decade. The latest improved manufacturing processes and enhanced module efficiency enabled are the key drivers of lower module costs. In addition, as project developers gain more experience and supply chain structures continue to develop in more and more markets, declining BoS costs have followed. This has led to an increased number of markets where PV systems are achieving competitive cost structures and resulted in falling global weighted-average total installed costs [1]. In 2019, significant total installed cost reductions have occurred across all the major markets such as China, India, Japan, Republic of Korea and the United States. An increasing number of cost competitive projects in India led to weighted average total installed costs of \$618/kW in 2019, around a fifth lower than in China. However, competitive costs structures are not confined to established markets anymore. Between 2010 and 2019, total installed costs have declined between 74% and 88% in markets where historical data is available back to 2010. The global capacity weighted-average total installed cost of projects commissioned in 2019 was \$995/kW, 18% lower than in 2018 and 79% lower than in 2010 (see graph in figure 6). Based on the costs of the developed projects around the globe, yearly variation of total installation cost and LCOE is given graphically in figure 9.

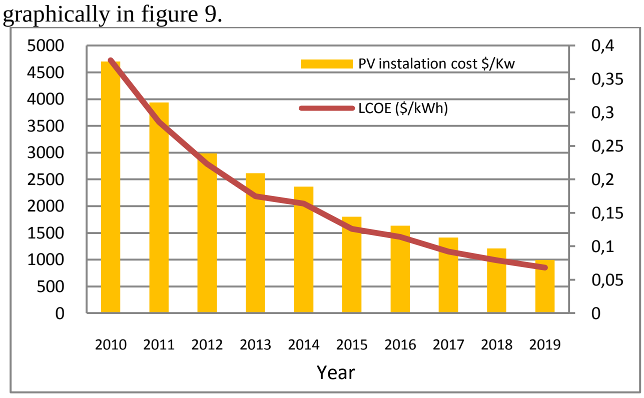

Figure 9: *Global weighted average total installed costs, capacity factors and LCOE for PV, 2010–2019 [1-3]*

An important driver of improved competitiveness historically, the downward trend in solar PV module costs continued during 2019. By the end of 2009 and 2019, crystalline silicon module prices declined between 87% and 92% for modules sold in Europe, depending on the type. The weighted average cost reduction could be in the order of 90% during that period. More recently the cost of mainstream module technology declined 14% between December 2018 and December 2019, reaching \$ 0.27/W. A wide range of costs exists, however, depending on the type of module considered, with costs for December 2019 varying from as low as \$0.21/W for the lower cost modules to as high as \$0.38/W for all black modules. The cost of high efficiency crystalline modules at \$0.37/W was slightly above thin film offerings, which sold for \$0.36/W during that period. These costs declines and the advances in the ability to securely operate the grid with high shares of variable renewables are not only decarbonizing the electricity sector but are unlocking low-cost decarbonization in the end-use sectors in conjunction with increased electrification. On average, in 2019, balance of system costs (excluding the module and inverter) made up about 64% of total installed costs. In 2019, total BoS costs ranged from a low of 48% in India to a high of 76% in the Russian territories. Overall, soft cost categories for the evaluated countries made up around 40% of total BoS costs and about a quarter, on average, of the total installed costs. In 2016, these values were a third and 17% respectively.

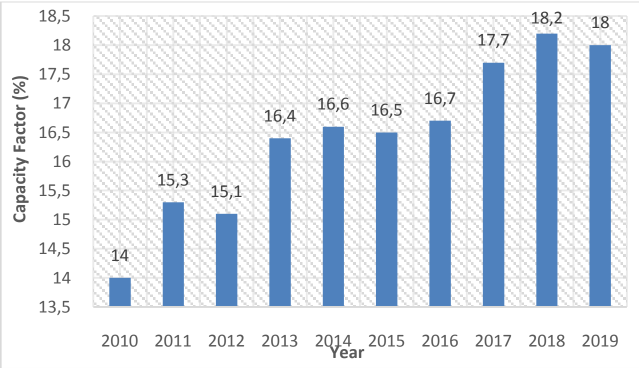

Figure 10: *Global weighted average capacity factors for utility-scale PV systems by year of commissioning, 2010–2019*

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The global weighted-average capacity factor for new, utility-scale solar PV, increased from 13.8% in 2010 to 18.0% in 2019. This was predominantly driven by the increased share of deployment in sunnier locations. A constant increased between 2010 and 2018 of the capacity factor is given in Figure 7 [11]. The development of the global weighted-average capacity factor is a result of multiple elements working at the same time. Higher capacity factors in recent years have been driven by the shift in deployment to regions with higher irradiation, the increased use of tracking devices in the utility-scale segment in large markets and a range of other factors that have made a smaller contribution (e.g., reduction in system losses).

9. Operation and Maintenance Costs

The Operation and Maintenance costs of utility-scale solar PV plants have declined in recent years. However, in certain markets, the share of O&M costs in total LCOE has risen, as capital costs have fallen faster than O&M costs. O&M cost declines have been driven by module efficiency improvements leading to reduced surface area required per MW of capacity. At the same time, competitive pressures and improvements in the reliability of the technology have resulted in system designs optimised to reduce O&M costs and improved O&M strategies that take advantage of a range of innovations from robotic cleaning to “big data” analysis of performance data to identify issues and preventative interventions ahead of failures driving down O&M costs and reducing downtime. For the period 2018-2019, O&M cost estimates for utility-scale plants in the USA have been reported at between $(10-18)/kW per year [8]. Recent costs there seem to be dominated by preventive maintenance and module cleaning, with these making up as much as 75% and 90% of the total, depending on the system type and configuration. The rest of the O&M costs can be attributed to unscheduled maintenance, land lease costs and other component replacement costs. The current benchmarks without inverter replacement are $11.5/kW/year (residential), $12.0/kW/year (commercial), $9.1/kW/year (utility-scale, fixed-tilt), and $10.4/ kW/year (utility-scale, tracking), significantly below previous O&M, only benchmark estimates [13]. Average utility-scale O&M costs in Europe have been recently reported at $10/kW/year, with historical data for Germany suggesting O&M costs came down 85% between 2005 and 2017, to $9/kW/year.

10. Results and discussion

PVWP configuration to supply water for irrigation to assist rural and remote areas in Albania was presented. This solution represents an alternative to simplify the installation process and to facilitate the PVWP, reducing the cost of electrical wiring network infrastructure design, installation time and maintenance. The perspective of a wide use of green power motivates the scientific community to study the possibility of fabricating PV modules providing autonomous water pump systems for irrigation (PVWP).

11. Conclusion

The present paper highlights some aspects related to autonomous PVWP systems district, including an universal understanding of the actual irrigation used for crop cultivation in Divjaka region.
The existing diesel-powered water pumps and electricity from the national distribution line can be stand-by source option and should be replaced and combined in perfect harmony with PVWP extracting the maximum solar radiation.
The high costs of the actual systems coming from the distance from national electricity distribution lines have and fuel prices are the main problems that should be considered.
Being aware of the high share (73%) fossil fuel used in agriculture sector the only way to decarbonize the sector is using more RES technologies such as PV and wind sources.
From economic point of view off-grid PV systems for irrigation can be more effective and can bring low specific costs.
As a conclusion, off-grid PVWP concept should be the only option and solution in the way to deep decarbonisation of the agriculture sector in Albania and also promoting crop cultivation in the region.

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