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# Solar Energy, a Viable Alternative for the Water Supply in Pressurized Systems

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In the interest of sustainable development and the minimization of climate change impacts, national and international policies are prioritizing the improvement in the use of the natural resources. In recent years, due to the modernization of irrigation schemes, where old open channel distribution networks have been replaced by new pressurized networks arranged on-demand that has increased the overall amount of energy for the irrigation supply. Also, as energy consumption in the pumping stations and GHG (greenhouse gasses) emissions are directly linked, the water supply the carbon footprint of the agricultural sector. This fact highlights the need to improve efficiency in the water-energy nexus, essential for the economic, social and environmental development of the sector.

The high energy requirements, 1003 kWh/ha and 1.56 kW/ha according to [1], and the rising costs highlight the need to reduce the energy dependence of the irrigation sector. Several studies have developed strategies for the improvement of the design and management of irrigation systems to reduce the energy requirements [2-5]. Therefore, in Spain, electricity is produced mainly from fossil fuels and minerals which are non-renewable resources which use produce significant environmental impacts. By contrast, renewable energy resources reduce the negative effects on the environment and contribute to the sustainable development of the agricultural sectors. In Spain, the irrigation season is mainly concentrated between March to October. Simultaneously, the PV (Photovoltaic) systems have their peak energy production these months. Then, solar radiation and evapotranspiration have parallel time distribution curves (monthly and daily), so the peak solar power generated coincide in time with the irrigation water requirements. Consequently, solar PV has the potential to be the most suitable renewable source for irrigation.

There are several configurations of PV systems, but the most common are the following:

**(a) Off-grid:** System is not connected to a grid so it is completely independent of the conventional energy supplier. The generated energy can be consumed instantly or stored in batteries (which is not economically viable for high power stations).

**(b) Grid-tie PV system, semi-autonomous electrical generation:** System is sized to meet the energy demand of the peak irrigation months. Therefore, the PV system generates excesses of energy in less water demanding months, which can be sold to the pool. When insufficient electricity is generated, overnight or lower radiation days, the energy from the main grid can make up the shortfall. Pool price is usually smaller than the commercial tariffs of the energy supplier.

**(c) Grid-tie PV system, net metering:** Net metering allows the design the PV system but considering the total annual energy demand and reducing the total installed PV power. Thus, the excesses of electrical energy generated by the PV system are fed back into the energy supplier's grid which is considered like a virtual battery and the annual energy balance (excess of energy supplied by the PV system and energy purchased to the supplier) is performed. Then, net metering system would reduce the power requirements for the PV system and therefore reduces the investment costs.

In recent years, PV systems for pumping water for irrigation [6,7] have already been used in agriculture. However, up to date, these systems have been applied to small irrigation areas with low power requirements (less than 10 kW). However PV energy have overcome the main obstacles for their use and they are currently suitable for high power requirements for irrigation. On the one hand, the purchase cost of the PV system is considerably cheaper than years ago (less than 1.2 €/W) because the price of the panels has been reduced in 80% (thanks to this, the payback period of typical irrigation systems has been reduced to 3-6 years). On the other hand, innovation and development of new technologies such as the "Sun Water" system (www.iwes.es) allows the use of conventional pumps (AC) with solar energy. The system requires variable speed drives to optimize performance of the pumps and try to keep pressure in a acceptable range of efficiency. However, more research is needed in optimization models to cope with variable energy availability while keeping relatively constant pressure and flow.

At present, solar energy is a technically and economically viable alternative, which offers great advantages over the power consumption of the network: Reduction of energy cost, the farmers´ profit is decoupled from fluctuations in conventional energy prices, no investment in batteries are required, clean and environmentally friendly energy source with practically zero $CO_2$ emissions to the atmosphere [8].

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