Use of Renewable Energy in Agriculture: Assessment of the Implementation of Solar Panels at Nfumueto Farm, Soyo, Angola

Giselle Barroso Leyva; Viktor Quengue Francisco

Trainee Assistant Nimi Ya Lukeni Higher University Institute, Agricultural Engineering *Soyo, Zaire, Angola*

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ABSTRACT

This study provides a preliminary assessment of the energy sizing of a solar photovoltaic system intended to pump water for irrigation at Nfumueto Farm, in the municipality of Soyo, Zaire Province, Angola. An exploratory and descriptive case-study design was adopted, using a mixed qualitative and quantitative approach based on semi-structured interviews, direct observation, an energy assessment, and documentary analysis involving three participants engaged in the farm's management and operations. The conventional system was reported to comprise two combustion-engine pumps, with an estimated combined consumption of 80 L/day. The installed photovoltaic system consists of nine VC630M78-H modules rated at 630 W each, giving a total installed capacity of 5.67 kWp. Assuming five peak sun hours per day and overall losses of 20%, daily energy production was estimated at 22.68 kWh/day. For a pump with an approximate power rating of 3 kW operating for eight hours per day, the calculated daily energy requirement is 24 kWh. The difference between these values is 1.32 kWh/day. This result is a simplified estimate and does not, on its own, demonstrate the system's operational feasibility, since local irradiance data, performance measurements, and complete hydraulic parameters were not available. An integrated energy and hydraulic assessment is therefore required before any changes to the installation can be recommended.

Keywords: renewable energy; solar photovoltaic energy; agricultural irrigation; water pumping; Nfumueto Farm.

INTRODUCTION

Energy availability is an important factor in agricultural performance, particularly in water abstraction and distribution for irrigation. In farms without access to the electricity grid, petrol- or diesel-powered pumps can create logistical dependence on fuel supplies and recurring operating and maintenance costs. Solar photovoltaic systems convert solar radiation into electricity at the point of use and may reduce this dependence, provided that the system is sized according to solar-resource conditions, the characteristics of the electrical installation, and the farm's hydraulic requirements.

At Nfumueto Farm, located in the Tombe area, municipality of Soyo, Zaire Province, irrigation was previously associated with the use of internal-combustion pumps. The property is not connected to the national electricity grid and has begun using a photovoltaic system to power an electric pump. Assessing the correspondence between the energy that the photovoltaic generator can supply and the energy actually required by the pumping system is therefore important for operation and for planning potential improvements.

The aim of this study is to conduct a preliminary assessment of the energy balance of the photovoltaic system used for irrigation at Nfumueto Farm. Specifically, it seeks to characterise the fuel consumption of the conventional system, estimate the daily output of the photovoltaic array and the pump's energy demand using the available data, and identify the additional parameters required for consistent energy and hydraulic sizing.

METHODOLOGY

The research was designed as an exploratory and descriptive case study using a mixed qualitative and quantitative approach. The unit of analysis was Nfumueto Farm, located in the Luela/Tombe area, municipality of Soyo, Zaire Province, Angola. The place name should be standardised according to the property's official administrative identification.

Data collection included semi-structured interviews, direct observation of the facilities and equipment, an energy assessment, and analysis of the technical and administrative documents made available. The purposively selected sample comprised three participants involved in the farm's management and energy operations. Qualitative information was organised through content analysis, while quantitative data were processed using descriptive calculations and estimates of consumption and production. As continuous instrument-based records and complete technical data sheets for all components were not available, the quantitative results should be interpreted as estimates based on the reported parameters rather than as experimental performance measurements.

The pump's daily energy use was estimated using the equation $E_d = P \times t$, where E_d is daily energy (kWh/day), P is the power considered (kW), and t is the daily operating time (h/day). Photovoltaic output was estimated using $E_{PV} = P_{PV} \times PSH \times PR$, where P_{PV} is the installed nominal capacity (kWp), PSH denotes daily peak sun hours, and PR is the overall performance ratio. For preliminary calculation purposes only, PSH = 5 h/day and PR = 0.80 were assumed, corresponding to assumed overall losses of 20%; these parameters were not derived from local measurements. Energy consumption calculated from the pump's nominal power does not replace measurement of its electrical input power or assessment of its actual operating profile. For hydraulic sizing, hydraulic power can be estimated using $P_h = \rho g Q H$, where ρ is the density of water, g is gravitational acceleration, Q is the flow rate, and H is the total dynamic head. The required electrical power also depends on the overall efficiency of the pump and motor. As reliable values for Q, H, and efficiency are unavailable, this component cannot be calculated accurately. Accordingly, the sizing presented here is preliminary and energy-based only.

RESULTS

Characterisation of conventional fuel consumption

The conventional irrigation system was described as comprising two internal-combustion pumps, one petrol-powered and the other diesel-powered. According to the records and estimates made available, each pump consumed approximately 20 L per operation and operated twice a day, resulting in an estimated combined consumption of 80 L/day. This estimate corresponds to approximately 2,400 L over a 30-day period and 29,200 L when annualised over 365 days. The monthly and annual figures are arithmetic projections that assume the daily consumption pattern remains constant throughout the period; they should not be interpreted as consumption measured in annual records.

Unit prices, purchase receipts, and complete maintenance records were not available to calculate annual fuel costs or make an economic comparison between the alternatives. In addition to fuel, the conventional system may incur costs for lubricants, maintenance, replacement parts, transport, and storage. Quantifying these expenses would require additional documentary evidence.

Existing photovoltaic system

The photovoltaic installation described at Nfumueto Farm comprises nine VC630M78-H modules, each with a nominal rating of 630 W. The total nominal capacity is therefore 9×0.63 kWp = 5.67 kWp. The system powers a submersible pump used for irrigation, with an approximate power rating reported as 3 kW. An operating period of eight hours per day was assumed for the energy estimate. The available information is insufficient to establish whether the 3 kW value refers to measured electrical input power, the motor's nominal power, or useful hydraulic power; it is therefore treated as a reference parameter supplied for the calculation rather than as a complete characterisation of the equipment.

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Estimation of energy demand and production

Based on the adopted parameters, the pump's daily energy use was estimated as E_d = 3 kW × 8 h/day = 24 kWh/day. This corresponds to 720 kWh over 30 days and 8,760 kWh over 365 days. These values are projections conditional on eight hours of daily operation at a constant power of 3 kW; they are not measured consumption. The annual estimate should therefore be distinguished from the value of 8,640 kWh obtained using the convention of 12 months of 30 days.

Estimated daily photovoltaic production before losses was calculated as 5.67 kWp × 5 h/day = 28.35 kWh/day. Applying the assumed performance ratio of 0.80 gives E_PV = 28.35 × 0.80 = 22.68 kWh/day. Compared with the estimated demand of 24 kWh/day, the arithmetic difference is 1.32 kWh/day. This comparison assumes that the peak sun hours and performance ratio adequately represent operating conditions, which has not yet been verified using local data. Moreover, daily energy production alone does not guarantee that power will be available when pumping is required; the irradiance profile, any energy storage, the inverter/controller, and the pump's operating conditions must also be considered.

Under the same assumptions, each module would contribute approximately 0.63 kWp × 5 h/day × 0.80 = 2.52 kWh/day. Dividing the estimated demand by the calculated production per module (24 ÷ 2.52) gives approximately 9.52 modules, which rounds up to ten modules. This is only a simplified energy-sizing result. Adding a module should not be treated as a validated solution until the inverter or controller's electrical characteristics and voltage and current limits, string configuration, cable and protection ratings, module compatibility, and the pump's response under actual power-supply conditions have been verified.

Table 1. Summary of energy parameters

Parameter	Estimated value
Existing panels	9 VC630M78-H modules
Power per panel	630 W
Installed photovoltaic capacity	5.67 kWp
Estimated production after losses	22.68 kWh/day
Pump power	3 kW
Assumed operating time	8 h/day
Estimated pump demand	24 kWh/day
Estimated daily difference	1.32 kWh/day
Calculated number of panels	10 modules (preliminary estimate)

DISCUSSION

The data indicate that irrigation operations previously depended on fossil fuels. The estimated consumption of 80 L/day is equivalent to approximately 29,200 L/year if the daily pattern is assumed to remain constant for 365 days. However, without invoices, unit prices, and maintenance records, the annual cost of the conventional system cannot be determined reliably, nor can the potential financial savings from the photovoltaic alternative be quantified.

Under the hypothetical conditions adopted, the photovoltaic system's nominal capacity of 5.67 kWp corresponds to an estimated output of 22.68 kWh/day, below the pump's calculated demand of 24 kWh/day.

The difference of 1.32 kWh/day indicates that the sizing requires further investigation, but it does not, by itself, establish the system's operational feasibility or infeasibility. The estimate depends on peak sun hours and overall losses that have not been verified at the site, and it assumes constant power and eight hours of operation. The calculation of ten modules should be interpreted as an initial approximation rather than a final engineering specification.

A conclusive assessment requires the energy and hydraulic components to be considered together. The required flow rate, static head, total dynamic head, operating pressure, pipe length and diameter, head losses, daily water volume, and crop water requirements should be measured or documented. Hydraulic energy depends on the product of flow rate and head, while the required electrical energy also depends on the efficiencies of the pump, motor, and conversion devices. For the solar component, irradiance or peak-sun-hour data representative of the site should be used, preferably as monthly time series, with particular attention to the period of highest irrigation demand. Where possible, the assumed overall loss factor of 20% should be broken down into temperature, soiling, cabling, conversion, and operational-mismatch losses rather than treated as a validated value. Without primary economic and environmental data, the payback period, monetary savings, and emissions reductions cannot be quantified.

Study limitations

Interpretation of the results is constrained by several important limitations: the absence of local irradiance measurements and time-series data on photovoltaic production; the lack of instrument-based records of the pump's electrical consumption; incomplete information on flow rate, total dynamic head, pump-set efficiency, and distribution-network characteristics; and the absence of comparable economic data. The assumptions of five peak sun hours per day and 20% overall losses are calculation assumptions, not values measured or validated for the site. The qualitative sample of three participants and the case-study design also limit the generalisability of the findings to other farms. Future studies should collect field data under different seasonal conditions and compare estimated production with actual measurements.

CONCLUSION

This preliminary analysis characterises the potential for using solar photovoltaic energy to support water pumping at Nfumueto Farm, but the available data are insufficient to confirm the installation's overall technical feasibility. The existing array comprises nine 630 W modules, for a total capacity of 5.67 kWp. Assuming five peak sun hours per day and overall losses of 20%, calculated production is 22.68 kWh/day. For the 3 kW pump operating for eight hours per day, estimated arithmetic demand is 24 kWh/day, yielding a nominal difference of 1.32 kWh/day between estimated demand and production.

The simplified calculation indicates that ten modules would be required to match the estimated energy demand under the assumptions adopted. However, this result is not a definitive recommendation to expand the array, because system suitability depends on validation of the solar resource, the pump's actual electrical power, its operating profile, and the compatibility of all components. Before modifying the installation, a field assessment is recommended, including local solar data, electrical performance measurements, flow rate, total dynamic head, head losses, pump-set efficiency, and crop water requirements. A reduction in fuel dependence is plausible, but economic and environmental benefits should be quantified only when verifiable data on costs, consumption, and operation are available.

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