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Feasibility of using solar energy for cold production

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Abstract

The phoenicultural sector occupies an important place in Morocco's agricultural development strategies. The country has seen increasing growth in the date packaging and cold storage units in hot areas where energy poses a critical environmental situation. The overall objective of this study was to enable the local population, especially the actors of the phoenicultural sector using the refrigerated units for the conditioning of dates, to benefit from the important solar potential enjoyed by the region, with a strong concern for reducing the energy bill and for participation in the national and international efforts to reduce the effects of climate change. The study made it possible to propose technical-economic solutions based on photovoltaic energy. It thus emerges that the use of this energy is essential as a curative solution to this challenging economic situation. Therefore, the context of the project is favourable to its success as a technical solution for reducing energy consumption.

Key words: Energy, photovoltaic, units, date, Morocco

Introduction

Since 2009, sustainable development has been a leitmotif of Moroccan policy. Renewable energies and energy efficiency are increasingly present in the political discussion in Morocco (Internationale Zusammenarbeit (GIZ), 2011). In a context of rising petrol prices, with a considerable impact on the balance of trade, they represent the most interesting alternative to reduce the country's economic vulnerability in the energy sector: they constitute an immense, almost untapped wealth for the country. The national energy strategy which foresees, on the one hand, the achievement of a primary energy saving of about 12 to 15% by 2020, and on the other hand, the increase of the share of installed power from renewable sources to 52% of Morocco's total power by 2030 (Ministry of Energy Morocco, 2009).

In parallel, a dynamism is being installed; by the installation of packaging units and cold storage of dates in Moroccan oases (UD) to improve the value chain of the date sector in the phoenicultural region.

The present work is a feasibility study of the equipment of date conditioning and cold storage units (UD) in photovoltaic solar production pilots. We will proceed to the diagnosis of the energy situation of UD in the municipality of Tamzmoute located in the province of Zagora and then we will propose technical solutions based on photovoltaic energy, it is a question of evaluating the technical and economic feasibility of photovoltaic installations for the power supply of refrigeration units.

Material and methods

Location of the study area: In Morocco, there is an important infrastructure for the conditioning and cold storage of dates, this infrastructure is based mainly in the date-producing phoenicultural areas, of which the province of Zagora has an important phoenicultural heritage. With an average irradiation exceeding 5 kwh/ m^2, the province of Zagora has considerable solar potential (MASEN, 2017). The unit of Tamzmoute is a unit for packaging and cold storage of dates, built in 2011, the unit has a cold storage capacity of 400 tons of dates.

Energy situation of the Tamzmoute unit: During the diagnostic phase, all installed electrical equipment were thoroughly examined, in particular:

- An inventory of energy-consuming equipment: this involves accounting for all the electrical appliances installed, such as transformers, refrigerators, pumps, sockets, air conditioners, motors, bulbs, sorting lines, dryers ... etc.;
- The collection of available information (invoices, diagrams of existing electricity networks, energy monitoring data, subscriptions and operating contracts...);
- Survey of the technical characteristics of the various electrical appliances installed (transformers, refrigerators, air conditioners, motors, sorting lines, dryers ...etc.);
- A review of energy management methods (pricing, nature and duration of contracts).

Study of Tamzmoute unit's energy demand: The study of the energy demand is a prerequisite for the optimised dimensioning of the photovoltaic solution. In order to design a photovoltaic system, the energy and power requirements was assessed. The calculation of the energy requirement was based on a combination of two methods: the monthly energy called for the UD resulting from the analysis of the electric bills; and the estimated operating time of each piece of equipment making up each refrigeration unit by listing all the electrical appliances to be supplied with their operating times.

The power requirement was obtained by analysing the load curve of each unit. The analysis of the load curve made it possible to precisely characterize the demand in terms of maximum power, load factor, etc. The analysis of the load curve was used to precisely characterize the demand in terms of maximum power, load factor, etc. The analysis of the load curve would make it possible to precisely characterize the demand in terms of maximum power, load factor, etc.

Study of the solar deposit: After calculating the energy requirement and characterizing the power requirement, it was necessary to evaluate the solar resource available in the site. These data were provided on a monthly basis and represent a statistical source to assess the availability of the solar resource throughout the year. These data were obtained from reliable sources such as: NASA, Helioclim-3 and Satellight. Illuminance or irradiance is defined as the power received by a surface, it was expressed in W/m^2 (watt per square metre), the I.S. (International System of Units) recommends using the symbol E (Renewable Energy World, 2003). Irradiance or irradiance is the energy received by a surface, it is expressed in J m^{-2} (joule per square metre), and the ISES (International Solar Energy Society) recommends the symbol H. It should be noted that, apart from the incidence of the atmosphere, solar irradiation depends on: the orientation and inclination of the surface, the latitude of the place and its degree of pollution, the time of year, the time of day, the nature of the cloud layers. The combination of all these parameters produces the variability in space and time of the daily irradiation. Meteorological maps are drawn up to get information on the average irradiation per day or over a year (NASA).

Development of solar photovoltaic production variants: Homer softwar: As far as the variants of solar photovoltaic production are concerned, we studied two scenarios for the unit:

Scenario 1: Photovoltaic powering of the unit in total autonomy.

Scenario 2: The combination of electricity and photovoltaic without storage.

Sub Scenario 2-1: The combination between electricity and photovoltaic without storage up to 100% of the maximum power.

Sub Scenario 2-2: The combination of grid and PV without storage up to 80% of the maximum power.

Under scenario 2-3: The combination of grid and PV without storage up to 60% of the maximum power.

For each configuration, we carried out a temporal analysis of the installation on an hourly basis using the HOMER (Hybrid Optimisation Model for Electric Renewables) energy modelling software. At each time step, the consumption was observed and compared to the PV production calculated according to the account deposit. Photovoltaic energy always had priority as it is not possible to postpone its use. In the case of a lack of this energy the demand was met by using batteries if they exist and if they are charged, otherwise the energy was imported from the electricity grid.

Subsequently, an economic balance and an estimate of the payback time was developed, based on the energy balance and taking into account the financial and macroeconomic parameters mentioned above. The investment criterion was the levelized cost of electricity (LCOE), which was calculated for each of the scenarios. The optimal scenario was one corresponding to the minimum LCOE. From the simulation, Homer allows to visualize the hour by hour behaviour of each equipment of the installation for all the simulated configurations. From these results, Homer presents a financial analysis over the duration of the project. Thus, for each architecture and configuration, we obtained the global cost of the updated KLWh (LCOE: Levelized Cost of electricity).

Sizing the photovoltaic station: Two main families of PV technologies existed. The first, based on crystalline silicon in thick film form, includes mono and poly crystalline and the second, based on thin films, includes amorphous silicon cells as well as others based on composites.

For the same power, the surface with the amorphous was double that of the polycrystalline and for the same surface of the module, the producible with the amorphous is half of the annual producible of the polycrystalline. Hence, we can conclude from the relevance of the choice of polycrystalline. A polycrystalline silicon photovoltaic module with a power of 250 Wc was adopted. In the remainder of the study, the choice of this PV panel was made to reflect the range of power that exists both on the Moroccan market and internationally. This power is available from almost all PV panel manufacturers. Technical data are as follows:

Power Nominal (Wc)	: 250
Current Nominal (A)	: 8.3
Voltage Nominal (V)	: 30.1
Current short-circuiting (A)	: 8.87
Voltage circuit open (Vco)	: 37.2
Dimension: length x height (m)	: 0.982x1.638

Results and discussion

Diagnosis of the energy situation of the Tamzmoute Unit: During the diagnostic phase, all the installed electrical equipment were thoroughly examined in order to collect the elements necessary to carry out the next stages of the study, in particular the daily energy balance corresponding to the month of full load operation (April, 2016).

From Table 1 it can be seen that cold rooms account for 50% of the total consumption of the unit.

Table 1. Energy consumption of the Tamzmoute Unit - April 2016

Equipement	Power (W)	Nbr	Total Power (kW)	Functioning (h/day)	Consumption (Kwh/day)
Refrigeration unit	30.200	1	30.2	6	181.2
Well pumping system	9.200	2	18.4	3	55.2
Drying ovens	4.000	2	8	3	24
Refrigeration unit	8.200	1	8.2	6	49.2
Lift truck	4.000	2	8	3	24
Cash register washer	4.000	1	4	3	12
Date washer	4.000	1	4	3	12
Sorting conveyor	4.000	1	4	3	12
Fluorescent tubes 80 cm	18	64	1.152	6	6.912
Fluorescent tubes 120 cm	58	130	7.54	6	45.24
Incandescent lamps	100	20	2	6	12
Glucosage Machine	4.000	1	4	3	12
Projectors	500	5	2.5	6	15
Total consumption of the unit (KWh/Month)			13 822.56		

Study of the unit's energy demand: The load curve makes it possible to evaluate the power demand on the network for different periods of the day. The analysis of this curve makes it possible to identify periods with peak consumption and periods of low consumption. Below are the annual load curves for the Tamzmoute unit (Fig.1). From the load curve it can be seen that the Tamzmoute unit calls for a maximum power of 97 KW during the month of April, whereas the power demand is minimal between July and November.

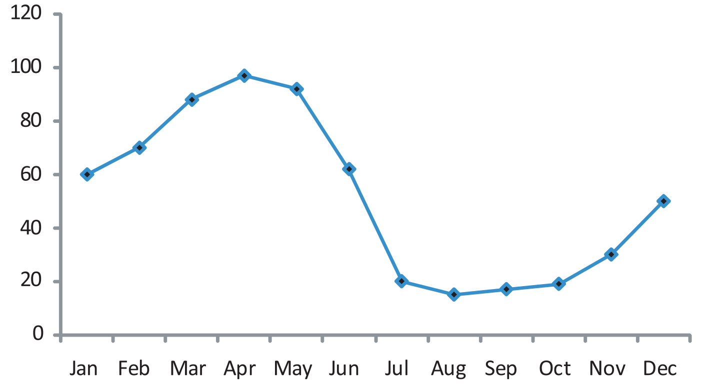

Fig. 1. Load curve of the unit of Tamzoute- Power from system kw (max) (2016)

Study of the solar deposit: After calculating the energy requirement and characterizing the power requirement, it is necessary to evaluate the solar resource available on the site (Fig. 2).

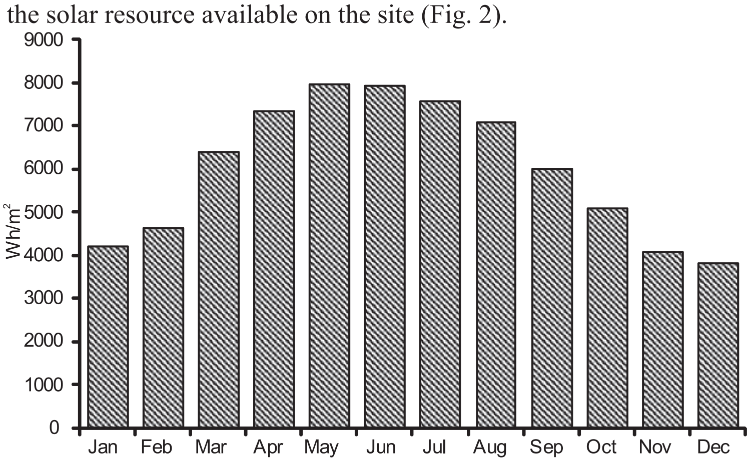

Fig. 2. Solar irradiation Wh/m²/jour at the Tamzmoute site

Ambient temperature is also an essential element in the development of a project photovoltaic. This factor has a huge impact on the performance of the panels because high temperatures affect the efficiency and lifetime of the sensors in the choice of technology and type of panels, since the loss coefficient of the panel depends on heating which varies from single to double between different materials.

The evolution of the average daily temperature at the site of Tamzmout for a year shows that the annual average is 20.3 °C and the peak exceeds slightly 41 °C (Fig. 3).

Development of solar photovoltaic production variants: The study of the two scenarios (the unit being powered in total autonomy by photovoltaic or a combination of electricity and photovoltaic without storage) was carried out through a simulation by the Homer software. This simulation first requires the definition of some input parameters of a financial and technical nature. Table 2 summarizes the general assumptions considered.

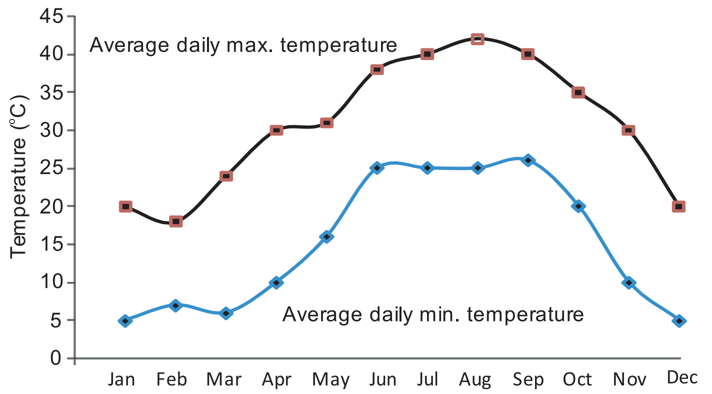

Fig. 3. Daily variation of ambient temperature in Tamzmoute (2016)

Table 2. General simulation assumptions

General assumptions	Unit	Value
Annual discount rate	%	8
Inflation rate	%	2
Service life	years	25
Average cost of grid electricity	MAD/Kwh	0,88
Maximum installed power	KW	97

The renewable energy production components (panels, inverters, battery) are generic type equipment with average technical and economic specifications (Table 3).

Table 3. Economic and technical data of the PV plant components

Component	Investment cost CAPEX	Operating cost OPEX	Service life (year)
PV	18.000 Dh/KW	100 Dh/KW/year	25
Inverter	4.000 Dh/KW	0	15
Batteries	3.000 Dh/KWh	100 Dh/KWh/year	15

The parameters resulting from the simulation of the different variants were: Power production by the PV plant, the investment costs (CAPEX), Operating and maintenance costs (OPEX), the cost per kwh produced by the PV plant, CO_2 emissions avoided (Table 4).

The scenario of the grid-connected photovoltaic power plant at of 60 % of the unit's peak power was the most favourable. This plant will have a power of 58.2 kWc. The total autonomy scenario is to be prescribed for economic (cost high investment) and technical (limited life span and need for maintenance of storage batteries) reasons. The installation of this power plant will allow a reduction in the energy bill missions by 37% and a reduction in CO_2 emissions into the atmosphere of 57 tonnes per year.

Calculation of the financial gain: The PV plant at 60 % of the maximum power represents the most advantageous model requiring an investment of 1.044.000, 00 MAD and with a update cost of 0,95 MAD/Kwh (Table 5).

This study showed that the project to equip the Tamzmoute date packaging and cold storage unit with a photovoltaic plant fits perfectly into the national and international context, as it will allow valorising this commodity at a lower cost while preserving the environment. The simulation results show the financial gain obtained by using this solar heritage.

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Table 4. Simulation results for the different scenarios studied

Scenario	Sub-scenario	Power of the PV plant (KW)	CAPEX (MAD)	OPEX (MAD/ year)	update cost of Kwh (MAD/KWh)	Output of the plant (KWh/yr)	Percentage of the energy production of the PV plant	Tons of CO_2 avoided (ton/year)
Scenario 1: Total autonomy through PV	Total autonomy by the PV	97	3.370.000	6.300	1,6	304.600	100	255
Scenario 2: Combining electricity and PV	PV power plant up to 100% of the maximum output	97	1.746.000	5.500	0 ,99	182.774,8	60	135,25
	PV power plant up to 80% of the maximum output	77,6	1.386.000	5.110	0,97	145.089,2	50	107,36
	PV power plant up to 60% of the maximum output	58.2	1.044.000	4.800	0,95	109.288	41	80,87

Table 5. Energy solution and calculation of the financial gain of the PV Plant for the Tamzmoute unit

Combination	PV plant power (KW)	Update cost per KWh (Dh/KWh)	PV plant production (KWh/year)	Grid production (KWh/year)	Percentage of PV plant energy production	Percentage of grid energy	Production Financial gain (KMAD/year)
Combination of electricity and PV:							
PV power plant up to 60% of the maximum capacity	58.2	0,95	109.288	194.712	41	59	82,54

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