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Photovoltaic water pumping systems as alternative to gasoline water pumping systems in agriculture in Cameroon: CO_2 emissions assessment

Kodji Deli [1] *, Noël Djongyang [1], Donatien Njomo [2] and Jean Gaston Tamba [3]

[1] Department of Renewable Energy, National Advanced Polytechnic School
University of Maroua, P.O. Box 46, Maroua, Cameroon
[2] Environmental Energy Technologies Laboratory, EETL
Department of Physics, Faculty of Science,
University of Yaoundé 1, P.O. Box 812, Yaoundé, Cameroon
[3] Department of Thermal Energy Engineering
University Institute of Technology, University of Douala, Cameroon

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Abstract - *With the decline in price of the photovoltaic's (PVs) and the increase in greenhouse gases due to the use of fossil fuels the use of photovoltaic as a power source for water pumping is becoming the more attractive solution instead of using diesel/gasoline generators. This paper deal with the optimal sizing of the water pumping system instead of gasoline generator for the irrigation of the onion farms in Cameroon it also discusses a share of greenhouse gas emitted from the cultivation of onions. The study uses the data generated from a survey carried out between 2014 and 2015 of consumption gasoline/lubrificant and water production from generators on the duration of the culture in the main production Area "10°35'N, 14°18'E". The results of the analysis indicates that the Life Cycle Cost, 'LCC' of the photovoltaic water pumping system depends on its capital costs (67 % of LCC) while the LCC of gasoline pumping system depends largely on recurring costs (79 % of LCC). The CO_2 emissions depend not only on the type of land but on the stage of plant growth. This research work also demonstrates that using the PV water pumping system can improve living conditions of farmers.*

Résumé - *Avec la baisse du prix des photovoltaïques et l'augmentation des gaz à effet de serre due à l'utilisation de combustibles fossiles, l'utilisation du photovoltaïque comme source d'énergie pour le pompage de l'eau devient la solution la plus attrayante au lieu d'utiliser des générateurs diesel / essence. Cet article traite du dimensionnement optimal du système de pompage de l'eau au lieu d'un générateur d'essence pour l'irrigation des exploitations d'oignons au Cameroun. Il aborde également une part des gaz à effet de serre émis par la culture des oignons. L'étude utilise les données générées par une enquête réalisée entre 2014 et 2015 sur la consommation d'essence / lubrifiant et d'eau produite par des générateurs sur la durée de la culture dans la principale zone de production "10 ° 35'N, 14 ° 18'E". Les résultats de l'analyse indiquent que le coût du cycle de vie du système de pompage d'eau photovoltaïque dépend de ses coûts en capital (67% du coût du cycle de vie), tandis que le coût de revient du système de pompage d'essence dépend largement des coûts récurrents (79% du coût du cycle de vie). .Les émissions de CO2 dépendent non seulement du type de sol, mais également du stade de croissance des plantes. Ce travail de recherche démontre également que l'utilisation du système de pompage d'eau PV peut améliorer les conditions de vie des agriculteurs.*

Keywords: Life cycle cost - PV pumping system - Greenhouse gas emission- Onions - Gasoline motor pump.

1. INTRODUCTION

Cameroon is located western central Africa, on the coast of the Gulf of Guinea, between the latitudes of 3°N - 13°N, and the longitudes of 8°E and 16°E. It covers an

* delikodji27@yahoo.fr

area of 475.442 km^2 and can be divided into two majors climatic zones. The equatorial climate characterized by heavy rainfall {more than 1000 mm of rainfall per year} this climate has many nuances, but all are based on the topography and proximity to the Atlantic coast.

The mainland have four seasons; two dry short periods seasons {December-January and July-August, with local variations}, while the coastal region known two seasons, one rainy season from March to November and one ^{2}dry from December to February. The atmosphere is humid throughout the year, the relative humidity is constantly close to the saturaton point and the insolation is less than 2000 h/year [1, 2].

The temperature varies less ({between 25 and 35 °C}. The Tropical area, with higher average temperatures and scarce rainfall, there are two seasons: a rainy season with a length of 6 to 4 months and a dry season from 4 to 6 months. Rainfall is scarce and dry seasons are more arid as one move away from the equator. The relative humidity is less than 60 % and the insolation is up to 2500 h/year [1].

Cameroon also has abundant land resources largely underexploited; a potential irrigable land estimated at about 240 000 ha and a very enterprising and dynamic rural populations and a highly strategic geographical position [3].

Cameroon is a country that holds the second hydroelectric potential in Africa after the Democratic Republic of Congo [4]. This potential is exploited to less than 5.5 %. Less than 1000 MW was installed in 2013 [5], which further justifies the low rate of rural electrification. Indeed only 20 % of the population having access to the national grid [5]. This situation is further complicated by the age of the transmission network and the lack of maintenance which cause unballasting. Rural area where agriculture is practiced depends essentially on conventional energy (generators, crude oil lamps) highly polluting and expensive maintenance frequency, which impacts on the economy and the environment (GHG emissions).

In Far north Cameroon, water is the primary source of life for mankind and one of the most basic necessities for rural development. The rural demand for water for crop irrigation and domestic water supplies is increasing. At the same time, rainfall is decreasing in many arid and sub arid countries [6]. The surface water is becoming scarce and the Groundwater appears to be the only alternative solution to this problem.

The investigation revealed that groundwater table is also decreasing [7], as a consequence of dewatering wells rather than expected by farmers as in all African sub Saharan regions, which makes traditional hand pumping and bucketing difficult. This makes mechanical pumping systems more attractive and appears to be a suitable solution for pumping water from wells which justifies the increased use of motor pump.

Nowadays, 80 % of farmers use motor pump (gasoline fuelled generators) while 20 % still use the manual drainage system at the study area, which is the largest production area with a production of 60.000.000 kg per year on the acreage over than 9.000 ha in 2001 [8], placing the onion as the first national vegetable speculation.

The onion represents 30 % of the production of fruits and vegetables, or about 1 % of GDP in 1997/1998 [8]. The onion is a significant source of income, since it represents 45 % of net income of farmers. The onion is cultivated especially during the dry season when the water resource is difficult to mobilize.

However, reliable solar photovoltaic (PV) pumps are now emerging on the market and are rapidly becoming more attractive than the traditional power sources (diesel, gasoline). These technologies, powered by renewable energy sources (solar), are especially useful in rural areas and remote locations where a steady fuel supply is problematic and skilled maintenance personnel are scarce [9-11].

In the far North Cameroonian region, there exists substantial solar potential to use photovoltaic sources of energy for supplying water pumping system. Thus, the photovoltaic water pumping systems, 'PVWPS' are very appropriate to use because of the availability of solar radiation and water in the no deep underground (12 m to 45 m head) in our area of study[12].

One of the most popular and promising applications of standalone photovoltaic (PV) systems nowadays is PV water pumping system, 'PVWPS' [10], the use of photovoltaic system is very attractive for pumping water in rural area of developing countries because of their low maintenance, no pollution, easy installation, reliability and possibility of unattended operation and capacity to be matched to demand. It contributes to socio-economical development of the developing countries and is a real mean for the reduction of the greenhouse gases. A state-of-the art of these systems is presented, considering their advantages and disadvantages in different applications[13, 14].

The system is much easier than others because they can be transported in pieces and reassembled on site [11]. A SPV water pumping system consists of a PV array, a DC/AC surface mounted/submersible/floating motor pump set, DC–AC inverter, pump controller, charge controller and batteries. The PV Array is mounted on a suitable structure with a provision of manual or automatic tracking.

Water is pumped during day and stored in tanks, for use during day time, night or under cloudy conditions. The water tank acts as storage and generally battery is not used for storage of PV electricity; however, for specific reliable requirements it can be used [14]. Depending on the components in the system, SPVWPS can broadly be classified as follow [15].

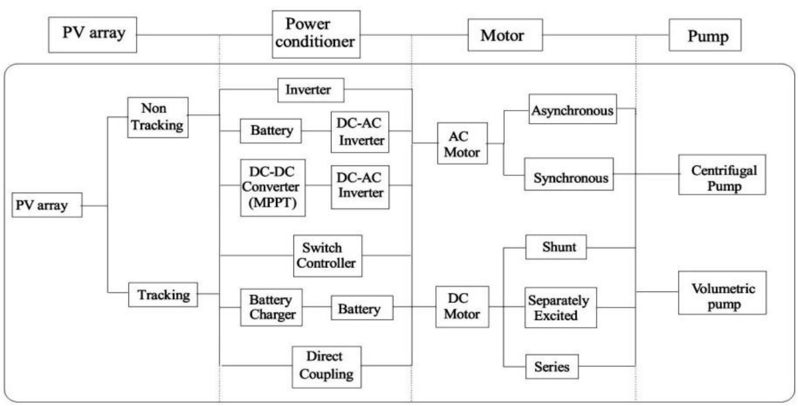

Fig. 1: The most common components of PV water pumping systems (Argaw *et al.*, 2001)

Water pumping systems are classified depending of the kind of the used pump (AC or DC) as described in figure 1, there are two broad categories of pumps being used in stand-alone PV systems around the world rotating and positive displacement. The output of these pumps is dependent on head, solar radiation (current produced) and operating voltage [11].

Pumps are well suited for pumping from shallow reservoirs, they can be tied directly to the PV array output but their performance will be improved by using an electronic controller such as a linear current booster or MPPT to improve the match between the pump and PV array [16].

The design of a photovoltaic water pumping system, 'PVWPS' strictly depends on the estimation of the crop water requirements and land use since the water demand varies during the watering season and the solar irradiation changes time by time [17], fund that for different configurations of PV pumping systems for irrigation the AC fixed system represented the best cost effective solution.

Many works have been carried out an shown economic and environmental benefits of photovoltaic solar pumping systems [18-20].

The design for the economic evaluation of the water pumping systems for rice cultivation using solar energy, gasoline fuel was proposed and led to a payback less than 10 years with DC solar pump without batteries [21]. others works analyses the feasibility of photovoltaic pumping system for irrigation and water supplies in rural, urban and remote regions, compared to traditional systems driven by diesel engines or electricity [19, 20, 22-24].

Analysis shows that photovoltaic pumping system is more economical than diesel generator pumping system. However, the high initial cost of the PV array is one of the main drawbacks of PVPSs [25, 26]. The investment payback for some PV water pumping systems is found to be 4-6 years [10].

Others previous research has been dedicated to study the performance of PVPSs. [27], show that the efficiency of the PV plant is not only strongly depends on irradiance but also depends on the module temperature. The average daily water flow rate of PVPS's is in the range of 5.3 m^3/kW_p - 26 m_3/kW_p, and their overall efficiency is in the range of 1.3 % - 5 % [22, 25].

The objective of this paper is to size a photovoltaic water pumping systems to replace the existing gasoline pumping system for onions production in rural areas of Cameroon, the life cycle cost analysis of the system is carried out in order to judge the viability a method is proposed to estimate the amount of carbon dioxide (CO_2) emissions saved by the use of water pumping facilities powered by a photovoltaic array instead of gasoline fuelled generators.

2. IRRIGATION TECHNIQUES

Irrigation is a well-established procedure on many farms and is practiced on various levels around the world. It allows diversification of crops, while increasing crop yields. However, typical irrigation systems consume a great amount of conventional energy through the use of electric motors and generators powered by fuel [28].

There are various irrigation methods used around the world ie flood, open channel, surface, sprinkler or drip irrigation, all these irrigation techniques have their advantages and disadvantages but depends mainly on the following factors: natural conditions, type of crop, type of technology [29], previous experience with irrigation, required labour inputs, costs and benefits [30], for the plain West of Shush in Iran analyzed that the suitability of the land depend on the soils and land characteristics.

In their study the results obtained by the comparison of two types of irrigation techniques showed that drip irrigation is more suitable than surface irrigation for most of the study area. The major limiting factors for the surface irrigation method were sandy soil texture and slope, however for drip irrigation methods soil calcium carbonate was the restricting factor.

3. GROUNDWATER EXTRACTION TECHNOLOGIES

Four types of technologies are associated with the extraction of groundwater: well types, well installation, pumps and power sources. A variety of well types are used, from simple open wells to simple cased (tube) wells to radial wells. The appropriate type for a given situation is dependent on the characteristics of the aquifer particularly, its depth, thickness, and static water level, the type of installation equipment available, energy and equipment requirements to pump the water to the surface.

Special techniques are available for locating appropriate sites for wells in areas of localized water sources, but these are unlikely to be necessary in the region under study because of the prevalence of the groundwater.

Well location is determined more by land ownership and area for utilization than by characteristics of the aquifer, although there are potential problems of well 'interference' if the wells are spaced close enough to overlap their 'cones of depression'. Where density of well spacing is such that there is substantial overlap, pumping yields decline and costs increase.

4. CHARACTERISTICS OF BOREHOLE AND GASOLINE GENERATOR

The boreholes, which are generally machine-made, have a relatively small diameter (less than 360 mm) and the collector column is either made of PVC or stainless steel and has a minimum internal diameter of 110 mm (4"). These structures have a depth of between 10 and 80 meters and can provide a large amount of water reaching 1 m^3/min. the characteristics of the mainly gasoline generator used are specified in the following table.

Table 1: Characteristic of gasoline pump

Model	WP20X
Connection diameter	2 inch
Delivery volume	600 l/min
Total head	26 m
Power speed	2.8 Ps, 3600 rpm
Weight	21 kg

5. SOLAR IRRADIATION IN THE STUDY AREA

The study of the annual daily average of solar radiation on a horizontal plane in Maroua show that the average of solar radiation intensity during all season is up to 4.9 kWh/m^2/day and exceeds 6 kWh/m^2/day [2, 31-33], as shown in figure 2.

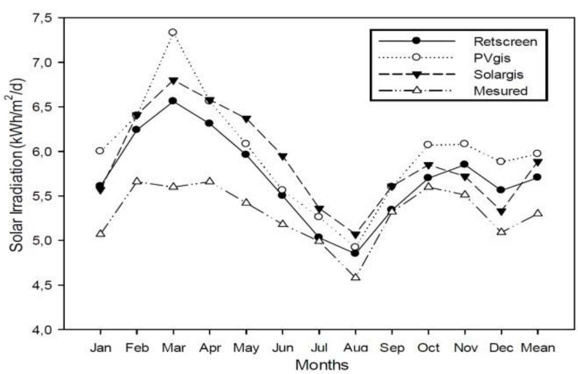

Fig. 2: Monthly averages of daily global irradiation in Maroua

The measured annual average of daily sunshine duration is between 6.71 h to 8.41 h, this represent annual sunshine hours between 2450 to 3040 hours [1]. From the above mentioned figures, it can be concluded that Cameroon has a high potential of solar energy which can be considered as a reliable energy source.

The fact that the higher water consumption for crops occurs in dry season (November to April), at the period of maximum availability of daily solar energy in the year; where a PV system is working at peak efficiency; makes the use of PV instead of gasoline motors pump very advantageous in water pumping. The water profile for the peak requirement for crops when using gasoline pump is presented in figure 4 below here we observe that motor pump operates from 7 am to 5 pm without laying that's why when sizing PV water pumping system we will take into consideration these data.

The daily solar radiation for the study area on horizontal module show us the availability of solar radiation up to 200 W/m^2 between 7 am to 5 pm, the PV pumping systems over the sun (without water storage) can be used, which will reduce considerably the cost of the installation. However PV pump cannot be used for more than 7 hours. For these reasons we will size PV system with a daily water of 30 m^3 and pumping hours in the range of 6 to 7 hours.

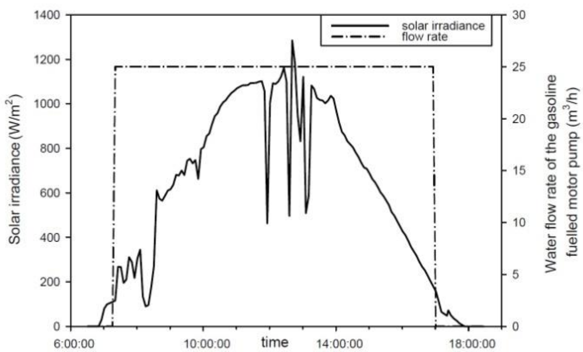

Fig. 3: Actual profile with gasoline water pump for crops and solar irradiation on horizontal surface in Maroua

6. MATERIALS AND METHOD

The research is carried out considering a case of a remote village of Maroua called Meskine which is one of the largest production areas. The methodology consists of investigating the viability of operating a water motor pump.

This study consists of designing for each onion cultivation area, an annual water demand, estimating energy requirements, 'gasoline' for pumping water. The energy consumption is based on the total fuel required to pump the annual water demand {which depends mainly on the type of land} the technical and economic analyses of systems are carried out.

6.1 Emission calculation

The greenhouse gas emissions from the cultivation of onions (attributable to fossil fuels) burned in the motor-driven pumps for water irrigation of onion fields are obtained by using the following equation [34].

$$E_t = \sum_i \left(FC_{i.t} \,.\, D_i \,.\, LHV_i \,.\, EF_{i,CO_2} \right) \tag{1}$$

where the subscript i represents the fuel type; $EF_{i,CO2}$ the national emission factor of CO_2 of the i^{th} fuel; LHV_i the national lower heating value on fuel type i and D_i is the national density at 15 °C on fuel type i [34]. $FC_{i,t}$ is fossil liquid fuels consumed on fuel type in period t .

6.2 Photovoltaic pumping system sizing

To complete the study of the economic viability of the two systems it is important to determine the size of different elements of the water pumping system. Thus the hydraulic energy required per day (kWh) is calculated based on the following equation[13, 35].

$$E_h = \rho g(h + \Delta H)V = n_s E_{pv} \qquad (2)$$

Where V is the volume of water required in m^3/day, n_s is the subsystem (motor, pump and an inverter) efficiency and E_{pv} is the PV energy.

The electric power of PV generator P_c (peak power) thus the following formula will be used [36, 37].

$$P_c = 2.725 \times 10^{-2} \frac{Q_j (h + \Delta H)}{K_P . \eta_{ond} . \eta_{mp} . E_i} \qquad (3)$$

Where Q_j is flow rate (m^3/day); h is the total pumping head (m); ΔH is the hydraulic losses (m); K_p is the array mismatch factor, that is, the ratio of the power output of the photovoltaic array under operating conditions to its power output at the maximum power point.

The generally accepted value for designing of a photovoltaic system is (0.85 – 0.90) on average [39]. η_{ond}, Inverter effectiveness (η_{ond}= 0.96) if no inverter is used, (η_{ond}= 1) in this case a DC motor is used.

η_{mp} , Daily mean effectiveness of the motor pump, Grundfos offers energy-efficient submersible pumps ranging from 1 to 280 m^3/h. The pump range consists of many pump sizes and each pump size is available with an optional number of stages to match any duty the efficiency of these pumps is in the range 0.3 to 0.85 depending on the type and the lifting head [39]. E_i, daily average irradiation kWh/m²/day, corresponding to the worst month of the year.

6.3 Life cycle cost analysis

Finally, in order to generalize a PV pumping system in a wide area of applications, their cost must be less expensive or comparable to the costs of the mechanical pumping alternatives(such as gasoline motor pump used in the study area). Here we present an analysis of the economic feasibility of the PV pumping system in comparison with systems using gasoline motor driven pump.

The economic study consists of determining first the capital cost for the PV system and gasoline motor pump alternative and then calculating the life cycle costs. The life cycle cost uses a combination of costs to measure the cost effectiveness of a specific pumping system. The life cycle cost of a system can be calculated using the following equation [40 - 42].

$$LCC = C_{ic} + C_{in} + C_r + C_0 + C_m + C_s + C_{env} + C_d$$

C_{ic}, initial costs, purchase price; C_{im}, installation and commissioning cost, C_r, replacement costs; C_0 operating costs (labour costs); C_m, maintenance and repair costs; C_s, Downtime costs; C_{env}, environmental cost; C_d, decommissioning costs.

For PV pumping system, the initial capital cost of the PV pumping system can be calculated by adding up the costs of the PV components (modules, the motor pump subsystem) and auxiliary costs. The auxiliary costs include the costs of the system engineering and planning, panel structure, wiring and miscellaneous items.

The engineering and planning cost is assumed as 9 % of the PV components cost. The panel supporting structure cost is taken to be about 5 % of the PV equipment's cost. The wiring and other items cost is considered to be 0.2 % of the PV subsystems cost [43], maintenance cost is taken as 2% of the initial cost [44]. The total initial investment of the PV pumping system is calculated as follows [27].

$$C_{ic} = C_{pv} + C_{sub} + C_{aux} \tag{5}$$

To calculate the life cycle cost, we take into account two phenomena that affect the value of money over time. The inflation rate, i, which is a measure of the decline in value of money. For example, if the inflation rate is 4 % per year, then an item will cost 4 % more next year.

Since it takes more money to purchase the same thing, the value of the unit of currency, in effect, is decreased. The discount rate, d, which is related to the amount of interest that can be earned on principal that is saved. If money is invested in an account that has a positive interest rate, the principal will increase from year to year.

For an initial amount of money which is invested at a rate of d per year where d is the percentage rate expressed as a fraction. After n years, the value of the investment will be [41].

$$N(n) = N_0 (1 + d)^n \tag{6}$$

In order to account for inflation, note that if the cost of an item at the time the investment was made is C_0, then the cost of the item after n years if the inflation rate is i per year, will be

$$C(n) = C_0 (1 + i)^n \tag{7}$$

If $C_0 = N_0$, the ratio of $C(n)$ to $N(n)$ becomes a dimensionless quantity, Pr, which represents the present worth factor of an item that will be purchased n years later, is given by

$$Pr = \left(\frac{1+i}{1+d} \right)^n \tag{8}$$

The present worth of an item is defined as the amount of money that would need to be invested at the present time with a return of 100 d % in order to be able to purchase the item at a future time, assuming an inflation rate of 100 i %. Hence, for the item to be purchased n years later, the present worth is given by [40, 41, 44].

$$PW = (P_r) C_0 = C_0 + C_0 \left(\frac{1+i}{1+d} \right) + C_0 \left(\frac{1+i}{1+d} \right)^2 + C_0 \left(\frac{1+i}{1+d} \right)^3 + \ldots + C_0 \left(\frac{1+i}{1+d} \right)^n \tag{9}$$

Letting $x = \left(\dfrac{1+i}{1+d}\right)$ then $PW = C_0\,(1 + x + x^2 + ... + x^{n-1})$ (10)

The expression can be simplified by observing that,

$$\frac{1}{1-x} = 1 + x + x^2 + x^2 + ... = \sum_{i=1}^{\infty} x^i$$

The cumulative present worth factor can be defined as [24].

$$P_a = \frac{PW}{C_0} = \frac{1}{1-x} - \sum_{i=n}^{\infty} x^i = \frac{1}{1-x} - x^n \sum_{i=n}^{\infty} x^i \qquad (11)$$

Or finally,

$$P_a = \frac{1-x^n}{1-x} \qquad (12)$$

Equation (11) is based on the assumption that the first year's supply is purchased at the beginning of the year at a time when the fuel is at its present value. Once the PW is known for all cost categories relating to the purchase, maintenance and operation of an item, the life cycle cost, 'LCC' is defined as the sum of the PWs of all the components.

The life cycle cost may contain elements pertaining to original purchase price, replacement prices of components, maintenance costs, fuel and/or operation costs, and salvage costs or salvage revenues. Calculating the LCC of an item provides important information for use in the process of deciding which choice is the most economical [43-45].

The diagram in figure 4 gives an overview of how the costing analysis was conducted and structured in the spreadsheet.

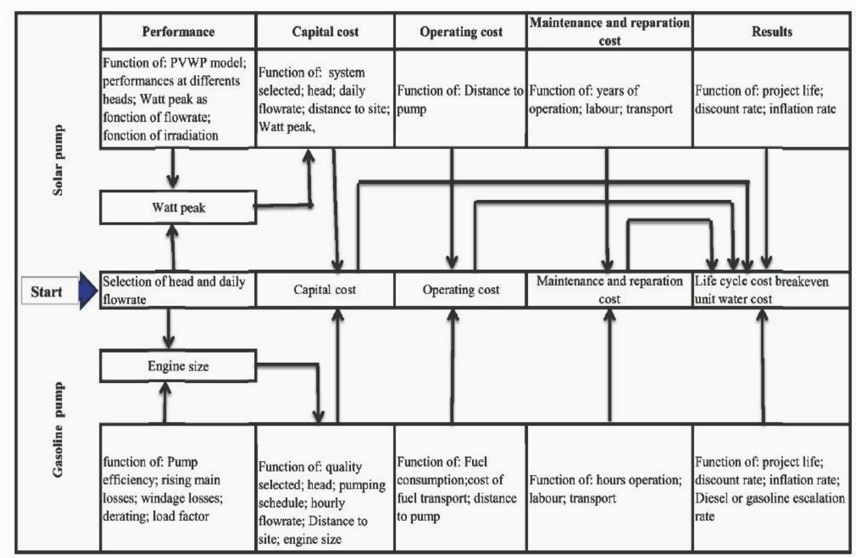

Fig. 4: Overview of the life cycle costing structure in the spreadsheet

7. RESULTS AND DISCUSSION

7.1 CO_2 emissions analysis

Two types of fuel {gasoline and lubricating oils} are consumed in motor pump for watering onion fields. **Tables 2** and **3** clearly show the following trend of consumption of fuel relative to the period of growing onions.

A corresponds tot he period from December 17 to February 10; watering is done once per day. **B** corresponds to the period from February 10 to March 31; watering is done once after two days. **C** corresponds to the period from 31 March to 07 April; watering is done once a week. **D** corresponds to the stage of the nursery from October 05 to November 12 for a period of 40 days. **E** corresponds to the stage of culture it self {this step begins by trans planting nursery} from November 13 to January 11. **F** corresponds to the stage of development to maturity {from January 12 to February 11} or post-harveststage.

Periods **A** to **F** are times operating generator, ie the period during which fuel is consumed and there fore period CO_2 emission in the atmosphere due to the consumption of fuel when pumping water for crops.

It should be noted here that there are two main phases of onion production **A**, **B** and **C** correspond here to the production of seeds, while **D**, **E** and **F** correspond to the production of onion bulbs. The investigations were carried in three different type of cultivation area **T1** {2500 m^2 of more clayey soil}, **T2** {2500 m^2 of more sandy soil} and **T3** {1 ha of clayey and sandy soil}.

Table 2: Gasoline consumption in land T1, T2 and T3 for different periods of irrigation

		Mean gasoline Consumption per Irrigation (liter)	Mean number Of irrigation	Mean total consumption (liter)
T1 (2500 m^2 of more clayey soil)	A	5.5	55	302.5
	B	6	25	150
	C	7.5	1	7.5
T2 (2500 m^2 of more sandy soil)	A	6	55	330
	B	6	25	150
	C	8	1	8
T3 (1 ha of clayey and sandy soil)	D	3	20	60
	E	6	18	108
	F	6.5	5	32.5

Table 3: Lubrifiant oil consumption in land T1, T2 and T3 for different periods of irrigation

		Mean total lubricating oils consumption (liter)
T1 (2500 m^2 of more clayey soil)	A	12.6
	B	6.25
	C	0.31
T2 (2500 m^2 of more sandy soil)	A	13.75
	B	6.25
	C	0.33
T3 (1 ha of clayey and sandy soil)	D	2.5
	E	4.5
	F	1.35

The CO_2 emissions due to pumping water for onion fields are obtained using the equation(1). In addition, the emission factors corresponding to the consumption of gasoline are specific to Cameroon [34], while those of lubricating oils are from the IPCC [46]. **Tables 4** and **5** illustrate the huge amount of CO_2 emitted into the atmosphere.

Table 4: CO_2 emissions attributable to the production of seeds in land T1 and T2

		A	B	C
T1 (2500 m^2 of more clayey soil)	Gasoline emission (kg CO_2)	721.12	357.58	17.88
	Lubricating oils emission (kg CO_2)	35.54	17.49	0.9
T2 (2500 m^2 of more sandy soil)	Gasoline emission (kg CO_2)	786.68	357.58	19.17
	Lubricating oils emission (kg CO_2)	38.48	17.49	0.95

Table 5: CO_2 emissions attributable to the production of onion bulbs in land T3

		D	E	F
T3 (1 ha of clayey and sandy soil)	Gasoline emission (kg CO2)	143.03	257.46	77.48
	Lubricating oils emission (kg CO2)	7	12.49	3.95

In general, 2872 kg of CO_2 is emitted per year in the atmosphere for the three onion cultivation area T1, T2, T3, these three area represent a surface of 1.5 ha. Moreover, we find the GHG emission depend on the nature of the cultivated area(soil), and the type of crop.

For the area **T1** (2500 m^2 of more clayey soil used for seeds production), 1150.51kg of CO_2 is emitted, for **T2** (2500 m^2 of more sandy soil used for seeds production), 1220.25 kg of CO_2 is emitted at same time for **T3** (1 ha = 4 times T1 or T2 used for onion bulbs), 501.48 kg of CO_2 is emitted.

7.2 Characterization of the PV pumping systems and economical parameters

By applying the equation (2) and (3), we obtain the main characteristic of PV pumping systems as presented in **Table 6**.

Table 6: Description of PV pumping system and economical parameters

Description of the over sun PV pumping system			
Lifetime of the system	25 years	solar irradiation	6kWh/m^2.day
power of modules	8870 Wc	Total Head	20 m
inverter power	8520 W	daily peak water volume	300 m^3/day
motor pump	SP 30-7 MS 6 7,5kW 16,6A	annual water volume	109500m^3
Economical parameters			
watt peak cost(module)	1.53€	panel supporting structure	5% of PV equipment cost
inverter watt cost	0.84€	wiring and other items	0,2% of PV subsystems cost
Engineering and planning cost	9% of PV components cost	Maintenance	2% of PV subsystems cost
discount rate	10%	discount rate	5%
inflation rate (PV)	0%	inflation of gasoline	0%
discount rate of PV	10%	discount rate of gasoline	5%

7.3 Life cycle cost analysis

The use of the equations (8), (9), (10), (11) and (12) for **T3** in accordance to the data in the **Table 1** leads us to the analysis of the life cycle cost of these systems. To carry out this analysis we set as lifetime of the system 25 years [47].

The cost of the watt peak in National market of Cameroonan Nigeria is in the range 0.84 € to 2.56 € according to technology, manufacturer. The watt of the inverter is in the range of 0.153 € to 1.53 €, the cost of other elements are taken as a percentage of the PV components cost [44].

For this study the watt peak cost and the watt of inverter cost are respectively 1.53 € and 0.84 €. The costs of different elements as the percentage of LCC are given in the **Table 7** for PV pumping system and for gasoline pumping system.

Table 7: PV and gasoline pumping system elements as % of LCC

PV system	%LCC	Gasoline system	%LCC
PV module	34.81	Gasoline motor pump	20.84
Array mount	2.66	Annual fuel	50.86
Motor pump	9.02	motor maintenance	15.61
inverters	35.15	Annualoil changes	4.89
Engineering & planning	4.79	Annual tune-ups	7.80
System maintenance	13.44		
Wiring and other items	0.13		
Total	100	**Total**	100

The evaluation of the LCC taking into account these tree parameters {capital costs, recurring costs and replacement costs} are presented in **Table 8** for PV and gasoline pumping system.

Table 8: PV pumping system LCC - gasoline pumping system LCC

	PV System (% LCC)	Gasoline System (% LCC)
Capital costs	66.67	3.88
Recurring costs	13.44	79.16
Replacement costs	19.89	19.96
Total LCC	100	100

For PV pumping system, initial cost represent 67 % of the total cost during it's lifetime. Initial cost is followed respectively by replacement cost 20 % and recurring cost 13 % however for gasoline pumping system, recurring costs represent 79 % of total LCC.

In order to determine the viability of the system. **Table 8** present the comparison of the LCC of PV pumping system with gasoline pumping system.

The cost of the PV pumping system if we take into account the initial cost which represents the largest expense of the system is 38900.6 € (€ =655FCFA) this cost is 7.7 times the cost of gasoline motor pump system (5905.43 €) actually used.

It is clear that the PV pumping system is not economically viable in the specific case of four study this is due to the fact that we suppose that the PV pumping systems works only during 4 months a year corresponding to the period of cultivation of onion in the dry season and not permanently (only 43 days a year).it is evident that for full time functioning PV pumping system is more viable than gasoline pumping system.

8. CONCLUSION

This study led us to analyze the technique for system reliability evaluation and the economic viability of the photovoltaic pumping system with the existing gasoline motor pump. The model based on the concept of the life cycle cost, 'LCC' which is considered as a good indicator of economic profitability was developed. It appears that in the context of cultivation of onions only, the PV pumping system is not economically viable relative to the gasoline motor-pump since it's cost is 7.7 times the cost of gasoline fuelled pump during their lifetime.

However, the system can be profitable if it is used full time {which requires an organization of farmers}. Moreover, the analysis shows that there is enormous quantity of CO_2 emitted in atmosphere. For the area **T1** 1150.51 kg of CO_2 is emitted, for **T2**, 1220.25 kg of CO_2 is emitted at same time for **T3**, 501.48 kg of CO_2 is emitted.

This emission depends on soil type and type of culture. The government can rely on this study to benefit carbon credit projects to realize the most environmentally friendly facilities and reduce the life cycle cost of the system.

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REFERENCES

[1] D. Njomo and L. Wald, '*Solar irradiation retrieval in Cameroon from Meteosat satellite imagery using the Heliosat_2 method*', ISESCO Science and Technology Vision, Vol. 2, N°1, pp. 19 - 24, 2006.

[2] T.C. Fotsing, D. Njomo, C. Cornet, P. Dubuisson, and J.L. Nsouandele, '*Acquisition and Study of Global Solar Radiation in Maroua-Cameroon*', International Journal of Renewable Energy Research, Vol. 5. N°3, 2015.

[3] Minader, 'Note d'information sur le Minader', 2013.

[4] F.H. Abanda, '*Renewable energy sources in Cameroon: Potentials, benefits and enabling environment*', Renewable and Sustainable Energy Reviews, Vol. 16, pp. 4557 - 4562, 2012.

[5] A.V. Wirba, A.A. Mas'ud, F. Muhammad-Sukki, A. Salman, R.M. Tahar, A.B. Ruzairi, A.B. Munir, and M. K. Ershadul, '*Renewable energy potentials in Cameroon: Prospects and challenges*', Renewable Energy, Vol. 76, pp. 560 - 565, 2015.

[6] Mott MacDonald International, '*Evaluation Hydrologique de l'Afrique Sub-Saharienne Pays de l'Afrique de l'Ouest*', Rapport de Pays: Cameroun, 1992.

[7] Pangire, '*Connaissance et usages des ressources en eau*', Ministère de l'Energie et de l'Eau et Global water, 2009.

[8] M. Cathala, N. Woin and T. Essang, '*L'oignon, une production en plein essor au Nord-Cameroun*', Actes du colloque, Garoua, Cameroun. Prasac, N'Djamena, Tchad - Cirad, Montpellier, France, 2002.

[9] International Energy Agency, '*Solar Photovoltaic Energy Technology Roadmap*', Edition, 2014.

[10] S.S. Chandel, N.M. Nagaraju and R. Chandel, '*Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies*', Renewable and Sustainable Energy Reviews, Vol. 49, N°C, pp. 1084 - 1099, 2015.

[11] E.R. Shouman, E.T. El Shenawy, and M.A. Badr, '*Economics Analysis of Diesel and Solar Water Pumping with Case Study Water Pumping for Irrigation in Egypt*', International Journal of Applied Engineering Research, Vol. 11, N°2, pp. 950 - 954, 2016.

[12] A.E. Cheo, V. Hans-Jürgen and F. Wendland, '*Modeling groundwater recharge through rainfall in the Far-North region of Cameroon*', Groundwater for Sustainable Development, Vol. 5, pp. 118 – 130, 2017.

[13] T. Khalib, '*Design of photovoltaic water pumping systems at minimum cost for Palestine: A review*', Journal of applied Sciences Vol. 10, N°22, pp. 2773 - 2784, 2010.

[14]V.C. Sontake and V.R. Kalamkar, '*Solar photovoltaic water pumping system - A comprehensive review*', Renewable and Sustainable Energy Reviews, Vol. 59, pp. 1038 – 1067, 2016.

[15] N. Argaw, R. Foster, and A. Ellis, '*Renewable energy for water pumping applications in rural villages*', NREL, 2001.

[16] N. Hamrouni, M. Jraidi, and A. Cherif, '*Theoretical and experimental analysis of the behaviour of a photovoltaic pumping system*', Solar Energy, Vol. 83, N°8, pp. 1335 - 1344, 2009.

[17] P.E. Campana, L. Hailong , and Y. Jinyue, '*Dynamic modelling of a PV pumping system with special consideration on water demand*', Applied Energy, Vol. 112, N°C, pp. 635 - 645, 2013.
http://dx.doi.org/10.1016/j.apenergy.2012.12.073.

[18] K. Meah, S. Fletcher, and S. Ula, '*Solar photovoltaic water pumping for remote locations*', Renewable Sustainable Energy Review', Vol. 12. N°2, pp. 472 - 487, 2008.

[19] S. Ould-Amrouche, D. Rekioua, and A. Hamidat, '*Modelling photovoltaic water pumping systems and evaluation of their CO_2 emissions mitigation potential*', Applied Energy, Vol. 87, N°11, pp. 3451 – 3459, 2010.

[20] A. Rahman and B.P. Bhatt, '*Design Approach for Solar Photovoltaic Groundwater Pumping System for Eastern India*', Current World Environment, Vol. 9, N°2, pp. 426 - 429, 2014.

[21] K. Treephak, T. Jutturit, S. Dhirasak, S. Jeerawan, and N. Patcharaprakiti, '*An economic evaluation comparison of solar water pumping system with engine pumping system for rice cultivation*', Japanese Journal of Applied Physics, Vol. 54, 08KH01, 2015.

[22] R. Posorski, '*Photovoltaic water pumps, an attractive tool for rural drinking water supply*', Solar Energy, Vol. 58, N°4-6, pp. 155 - 163,1996.

[23] Z.S. Ahmet and R. Shafiqur, '*Economical Feasibility of Utilizing Photovoltaics for Water Pumping in Saudi Arabia*', Hindawi Publishing Corporation International Journal of Photoenergy, ID 542416, Vol. 2012, 9 p. doi:10.1155/2012/542416, 2012.

[24] G. Misrak, A. Assefa, and M. Molinas, '*Feasibility study of a solar photovoltaic water pumping system for rural Ethiopia*', AIMS Environmental Science, Vol. 2, N°3, pp. 697 - 717, 2015.

[25] I. Odeh, Y.G. Yohanis, and B. Norton, '*Influence of pumping head, insolation and PV array size on PV water pumping system performance*', Sol Energy, Vol. 80, N°1, pp. 51 - 64, 2006a.

[26] T. Khatib and W. Elmenreich, '*Novel simplified hourly energy flow models for photovoltaic power systems*', Energy Conversion and Management, Vol. 79. pp. 441 - 448, 2014.

[27] S. Chokmavioroj, '*Performance of a 500 kWp grid connected photovoltaic System at Mae Hong Son Province Thailand*', Renewable Energy, Vol. 31, pp. 19 - 28, 2006.

[28] V.B. Shinde and S.S. Wandre, '*Solar photovoltaic water pumping system for irrigation: A review*', African Journal of Agricultural Research, Vol. 10, N°22, pp. 2267 - 2273, 2015.
http://www.fao.org/docrep/s8684E/s8684e08.htm

[29] http://www.fao.org/docrep/s8684E/s8684e08.htm

[30] M. Albaji, B.N. Saeed, A.K. Hydar and N. Abdali, '*A Comparison of Different Irrigation Methods Based on the Parametric Evaluation Approach in the Plain West of Shush, Iran*', Irrigation and Drain, Vol.59, N°5, pp.547–558, 2010.

[31] http://www.rncan.gc.ca/energie/logiciels-outils/7466

[32] http://re.jrc.ec.europa.eu/pvgis/apps4/MRcalc.php

[33] https://solargis.info/purchase/#tl=satellite&ot=CLIMDATA

[34] J.G Tamba, D. Njomo, and E. Tonye-Mbog, '*Assessment of CO_2 Emissions in the Petroleum Refining in Cameroon*', Universal Journal of Environmental Research and Technology, Vol. 1. N°4A, pp. 455 - 466, 2011.

[35] A. Al-Badi, H. Yousef, T. Al Mahmoudi, M. Al-Shammaki, A. Al-Abri and A. Al-Hinai, '*Sizing and modelling of photovoltaic water pumping system*', International Journal of Sustainable Energy, 2017. DOI: 10.1080/14786451.2016.1276906.

[36] I. Odeh, Y.G. Yohanis and B. Norton, '*Economic viability of photovoltaic water pumping systems*', Solar Energy, Vol. 80, N°7, pp. 850 – 860, 2006b.

[37] G. Zvonimir and J. Margeta, '*A model for optimal sizing of photovoltaic irrigation water pumping systems*', Solar Energy, Vol. 81, N°7, pp. 904 – 916, 2007.

[38] M. Al-Smairan, '*Application of photovoltaic array for pumping water as an alternative to diesel engines in Jordan Badia, Tall Hassan station: Case study*', Renewable and Sustainable Energy Reviews, Vol. 16. pp. 4500 - 4507,2012.

[39] Grundfos Data Booklet, '*SP Submersible pumps, motors and accessories 50Hz*', SPA.

[40] L.Y. Maystre, '*Initiation aux calculs économiques pour les ingénieurs*', 1ere Edition, Presses polytechniques romandes, 1985.

[41] R.A. Messenger and J. Ventre, '*Photovoltaic Systems Engineering*', 2nd Edition, Taylor & Francis e-Library, 2005.

[42] A.A. Ghoneim, '*Design optimization of photovoltaic powered water pumping systems*', Energy Conversion and Management ' Vol. 47, pp. 1449 - 1463, 2006.

[43] F. Lasnier and T. Ang, '*Photovoltaic Engineering Handbook, Asian Institute of Technology*', ICP Publishing Ltd. Bangkok, Thailand,1990.

[44] D. Rekioua and E. Matagne, '*Optimization of photovoltaic power systems*', Springer, 2012.

[45] P.E Campana, H. Li, J. Zhang, R. Zhang, J. Liu, and J. Yan, '*Economic optimization of photovoltaic water pumping systems for irrigation*', Energy Conversion and Management. Vol. 95. pp 32 – 41, 2015.

[46] IPCC, '*IPCC Guidelines for National Greenhouse Gas Emissions*', V.2. <http://www.ipcc-nggip.iges.or.>2006.

[47] G.E. Ahmad, '*Photovoltaic-powered rural zone family house in Egypt*', Renewable Energy. Vol. 26, N°3, pp. 379 - 390, 2002.