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Energy production and financial analysis of photovoltaic energy plants in Ivory Coast

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Abstract

One key factor for boosting economic growth in developing countries is the energetic independence of the countries. Renewable energies are well suited for such purpose even if effective dissemination of renewable energies is their production price. The energy production of solar plants is highly dependent of both sun radiation and climate data and therefore dependent of their location. This paper reports on the economic and financial calculations related to the energy production of a standard 20 kW photovoltaic plant connected to the electric network and located in Ivory Coast (Côte d'Ivoire). Its economic profitability in terms of economic returns of the electricity production is calculated by using capital budgeting techniques. It is demonstrated that when photovoltaic plants are considered as economic assets, the knowledge of financial and economic characteristics of the country as well as the geographical localization of photovoltaic plants, have to be taken into account in order to assess the profitability of the investment. The Levelized Cost of the Energy generated for the photovoltaic plant during its expected time of operation (25 years) is calculated and compared with other economical parameters.

Keywords : *photovoltaic energy production, solar energy investments, capital budgeting, net present value, profitability, levelized cost of energy, Ivory Coast.*

Résumé

Production d'énergie et analyse financière d'une installation photovoltaïque en Côte-d'Ivoire

Un facteur clé pour stimuler la croissance économique dans les pays en développement est l'indépendance énergétique de ces pays. Les énergies renouvelables sont bien appropriées pour atteindre un tel objectif, même si la vulgarisation effective des énergies renouvelables dépend de leur prix de production. L'implantation des panneaux solaires est fortement dépendante à la fois de l'ensoleillement et des données climatiques. Cet article présente les calculs économiques et financiers liés à la production d'énergie électrique d'une installation photovoltaïque de 20 kW standard connectée au réseau électrique et située en Côte d'Ivoire. Sa rentabilité économique en termes de retour sur investissements de la production d'électricité est calculée en utilisant la méthode du capital budgétisé.
Il est démontré que quand on considère des installations photovoltaïques comme des atouts économiques, la connaissance des caractéristiques financières et économiques du pays aussi bien que la localisation

géographique de l'implantation, doivent être pris en compte pour évaluer la rentabilité de l'investissement. Le coût de l'énergie produite par l'installation photovoltaïque pendant sa durée opérationnelle (25 ans) est calculé et comparé avec d'autres paramètres économiques.

Mots-clés : *production d'énergie photovoltaïque, énergie solaire, investissement, budgétisation, capital, rentabilité, coût moyen actualisé de l'énergie, Côte d'Ivoire.*

1. Introduction

It is a proven fact that there is a strong relation between energy consumption and economic growth. In this regard the academic literature also shows that power consumption is a key factor for the economic dependence of countries. For developing countries, which expect an ongoing rise in energy consumption, the establishment of a sustainable and independent energy sector is an opportunity factor that increases their chances for economic growth. Indeed renewable energy sources meet the objectives pursued by developing countries: energetic independence, deliverance of the necessary energy for economic growth, and sustainable growth. Among the renewable energies, solar energy is nowadays in position to offer many advantages for both developed and developing countries, such as the availability of technology, technology know-how is not required because installation and control of the power plants is quite easy, availability of raw material used (sunlight), and independence of huge investments for production because the implantation of solar energy does not require large production plants and can be scaled at the desired size. That is a guaranteed path to ensure the ongoing goals of sustainable growth [1].

According to The Global Status Report on Renewable Energy 2014 [2], considering only net investment in new power capacity in developed countries, the renewable energy sources outpaced fossils fuels for the last four years. This experience should be taking into account by developing countries and promote new investments in renewable energies and do not make the same mistakes made in the past in developed countries. So, it is important to know how investments in solar photovoltaic (PV) plants can provide both ecological and economic benefits. This evidence can be stated in Côte d'Ivoire, a developing county in Africa with excellent conditions for solar PV plants. This paper reports on the usage of capital budgeting techniques for analyzing the profitability of a standard investment in a PV solar plant installed in Côte d'Ivoire. We will show how to calculate the energy production of a PV solar plant in Cote d'Ivoire as well as the financial and economical analysis related to such installation through the Cash Flow generated by the operation of solar PV plant. Standard economic parameters related to investments such as Net Present Value, Internal Rate of Return and Pay Back of the investment are also described and analyzed. Further, for both investors and consumers it is essential to be able to compare energy costs and in that sense the Levelized Cost of Energy (LCOE) is a suitable concept that deserves to be taken into account. The LCOE is a measure of the energy costs for a given energy installation and depends on the characteristics and life of such installation. So, we estimate the LCOE for a solar PV plant in Côte d´Ivoire. These calculations allow us to draw conclusions about the suitability of electric production through PV energy.

2. Material and methods

2-1. experimental area

Studies are carried out in Kétesso, a village of Ivory Coast (Côte d´Ivoire) in the Sud-Comoe region, about 160 km from Abidjan *(see **Figure 1**)*.

Figure 1 : *location of the study area, in Kétesso (Côte d'Ivoire)*

2-2. Energy production in photovoltaic plants

The main goal of PV technology is to convert the sunlight into direct current (DC) electricity without the need for chemical reactions or fuel. The generated electric energy can be stored in batteries or can be feed into the electric network by using a device named inverter, which is used to convert this DC electricity into alternating (AC) current. Indeed since PV plants are able to feed AC electricity directly in to the network through the use of very efficient inverters the PV solar energy has boosted the implantation of PV solar energy plants because the simplicity and lower cost of this systems with respect to those using batteries. The assessment of the exact electrical output depends on complex factors, such as the angle, direction and efficiency of the panels, sunshine, temperature and weather. However, it can easily estimate the power output if some condition are met. Electrical output varies and is dependent upon factors such as the amount of available light, the position and angle of the solar panels, ambient temperature, the efficiency of the panels and the voltage supplied by the system. Calculating how many kilowatt-hours (kWh) of electricity are produced by a solar system is often a challenged activity because conditions can change in seconds, but a good estimate of the average power production can be made using straightforward techniques.

To produce the maximum energy the PV modules have to collect the greatest amount of sun photons and to achieve this goal PV modules must point the optimal direction to harvest the amount of solar radiation. The best placement for solar panels depends on the location where they are installed. Solar PV panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere. It has been taken into account that true north is not the same as magnetic north. However, true north or south can be easily found by using the standard Global Position System (GPS) devices, which nowadays are available in practically any smart phone. The next issue is related to the tilted angle from horizontal. Books and articles on solar energy often give the advice that the tilt should be close to the latitude where the PV installation is located [3]. Given the latitude in Cote d'Ivoire, near the Equator, all fixed PV installations should keep an angle lower than 5 degrees with respect to the horizontal, which in practice means that the PV modules can be mounted parallel to the ground. Keeping panels clean, in full sunshine and pointing directly toward the sun will maximize output. However such systems involve the use of sun trackers to keep the surface of solar modules always perpendicular to sun. This kind of systems is already available but in this example we are going to refer to static PV modules without sun trackers.

Once the PV modules are correctly positioned we still need to know the amount of solar radiation hitting the PV modules to calculate their energy production. Such information is available in specialized websites. See for example the link [4]. The solar radiation that hit a PV module located in a determined location can be expressed in terms of power or energy. However there are some parameters that can be very useful to calculate the expected production of a PV module. Equivalent Sun Hours (ESH) refers to the equivalent number of hours per day when solar irradiance averages 1 kW/m^2. For example, if a location receives 4 EHS means that it has received the equivalent of 4 hours at 1 kW/m^2 per hour 4kWh/m^2), although it may have been accumulated at varying rates over a much longer period. This is a very useful concept because it allows calculating, in a simple way, the electricity production of a PV installation over a given period. For obtaining the electricity production of a 20 kW PV installation the simplest method is to multiply the Equivalent Sun Time in the location by the peak power specified by the manufacturer for the PV modules. Actually all PV modules are tested under AM1.5 conditions which refers to a solar irradiation of 1 kW/m^2. Therefore the simplest way for calculating the electricity production of a PV installation over a period is to multiplying the ESH by the peak power of the modules specified by the manufacturer. Actually all PV modules are tested under AM1.5 conditions which refers to a solar irradiation of 1 kW/m^2.

So, the technical and economical calculations are given for photovoltaic installation with a nominal power of 20kWp. The size selection is based on the accessibility for small and medium size companies as well as for households. Let us define the main characteristics of a 20 kWp PV solar installation. PV installation can operate connected to the electrical grid or isolated. In the last case batteries or some element to store energy is required. Our PV installation will be connected to the grid and then the owner of the installation can use the energy generated by its PV installation, inject energy to the grid when it is not required or collect energy from the grid in case of necessity. Indeed, PV solar plants connected to the grid are the smartest way to generate, distribute and use electrical energy. Of course, the use of the electric network has some cost and will be taken into account. A PV solar plant is made of solar modules and if it is connected to the network an inverter is the required. The inverter is an electronic device that converts the DC electricity generated by the PV modules to AC in order to inject this energy into the network. The nominal power of the PV plant is defined by the conversion power of the inverter, i.e. 20 kW. However as the solar irradiation change along the day it is usual over dimensions the PV modules by about 10%. Standard Si-PV modules have a nominal power of 250 W, so to have solar fields of 22 kW an amount of 88 Si-based PV solar modules are required as it is specified in ***Table 1***. The area occupied by the solar panels of such installation is approximately 150 m^2.

Among all different semiconductors that can be used for photovoltaic conversion of sun light into electricity, silicon is the most common material and the majority of PV solar cells and PV solar panels are based in this material even though in the last decade other semiconductors such as CdTe, CIGS and TiO_2 have reached the industrial level and they are nowadays available in the market.

Table 1 : *Definition of a 20 kW solar PV Plant (Surface 150 m²)*

Component	units	Power (kW)
250 W Si-based PV Modules size : 1675x1000 mm	88	22
20 kW Inverter	1	20
Controller	1	-
Metallic structure to hold PV modules	88	-

Besides, there is an excitant competition all over the world for boosting up the efficiency of PV solar cells. In this paper we have choose Si-based solar modules because are the most standard but solar panels based in semiconductors such as CdTe, CIGS, etc. are already in the market and the production and economic issues described here are independent of the kind of module chosen. Let us calculate the energy production in Cote d'Ivoire for the 20 kW solar PV plant defined in ***Table 1***. ***Table 2*** displays the latitude and solar irradiation data of Côte d'Ivoire according to [4]. The Equivalent Sun Time and the estimated energy production for a 20 kW PV plant is also included.

Solar radiation data were obtained from PVGIS [5]. PVGIS is a tool that allows us to estimate the electricity produced by a PV solar system in a year. The outcome that provides PVGIS is free and online, covering the geographical areas of Europe, Asia and Africa. PVGIS takes into account the radiation losses due to reflectance, other climate issues affecting the performance of the PV system and the net efficiency of the electric setup. In the studied case total loses are estimated to be 18.7%. Taking into account that the average energy consumption in 2008 was 203.5 kWh per capita, the energy produced by the 20 kW PV plant described before will supply the requests of electricity for a population of 168 persons per year.

Table 2 : *Solar irradiation data and estimated electricity production for a 20 kW PV plant located in Kétesso (Côte d'Ivoire)*

City	Location	Solar irradiation (Kwh/m²)	Equivalent Sun Time (h/year)	Theoretical electricity production (Kwh/year)	Net electricity Production (Kwh/year) (losses 18.7%)
Kétesso (Côte d'Ivoire)	5°52' N, 3°10'3 W Elevation : 102 m. asl	1,910	1,910	42,020	34,100

2-3. Cost of a 20 kW PV solar plant

The main producers of PV modules are Germany and China. International competition between producers makes the price of a photovoltaic installation in any part of the world does not differ from the part that refers to the installation itself, ie modules, inverters or controller and holders. Consequently, for the capital outlay of the modules are taken in international prices for a standard installation. The part that differs compared to other countries is related to installation labor costs, so these were taken into account labor costs Ivory Coast. ***Table 3*** displays the required disbursement for a nominal 20 kW photovoltaic system described before with prices expressed in local currency CFA. The exchange rate against the euro that has been used is 1 € =

655.96 CFA. As usual in this type of technology most of the installation (about 80%) are solar modules and the labor cost represents only 20%.

Table 3 : *Capital outlay for a nominal 20 kW solar PV plant in euros and in CFA*

Component	€	€/W	CFA	CFA/W	%
PV Modules, Inverter, Controller and holders.	21,340	1.07	14,000,000	700	78.1
Installation Labor Cost	5,984	0.30	3,925,264	197	21.9
Total Cost	27,324	1.37	17,925,264	897	100.0

2-4. Basis for economic study of PV solar plants

A techno-economic analysis has been used for project cost control, profitability analyses, planning, scheduling and the optimization of operational research, etc. For PV systems, it is necessary to work out their economic viability so that users of this technology can know its importance and can utilize the area under their command to their best advantage. An effective economic analysis can be done using cost analysis knowledge with cash flow diagrams. First of all, we defined Cash Flow as movements of money in and out of any business; indeed it is the primary indicator of business health [6]. Several Capital Budgeting Criteria have to be used to analyze the profitability of the investment made. Payback (PB), Net Present Value (NPV) and Internal Rate of Return (IRR) are widely used to conduct profitability analyses [7]. PB is the number of years required to recover the initial investment exactly (Capital Outlay), and is computed by summing the annual cash flow values and by estimating the period throughout the relation.

A PB analysis provides an easy-to-apply and intuitive decision process. However, PB undergoes many well-known deficiencies as an investment analysis tool, and the most obvious kind is the inability to distinguish between short- and long-lived investments. The NPV is the difference between the value of incomes and the expenses incurred from an investment until the date the investment was made. Thus the NPV provides an estimate of the net financial benefit provided to the organization if this investment is undertaken [8]. A positive NPV means positive surplus, indicating that the investor's financial position will improve if the project goes ahead. Obviously, a negative NPV indicates financial loss.

$$\mathrm{NPV} = -\mathrm{D} + \sum_{j=0}^{n} \frac{\mathrm{CF_i}}{(1+\mathrm{i})^{j}} \qquad (1)$$

Where D is the capital outlay, i is the interest rate, and n is the technology life. Despite the NPV being easy to use, because it is an intuitive tool, it also presents some limitations in terms of : (i) the discount rate chosen for its estimation; a very low interest rate value, an alternative with profits spread far into the future may unjustifiably appear more profitable than an alternative whose profits are more quickly made, but are of a smaller amount in undiscounted terms; (ii) the distinction between a project with capital outlay and of lower cost, thus the NPV does not offer any indication of the scale of efforts required to achieve the results. The IRR is a discount of investment worth and is used as an index of profitability for the appraisal of projects. The IRR is defined as the rate of interest that equates the NPV of a series of Cash Flow to zero. Mathematically, the IRR satisfies the equation :

$$0 = -\mathrm{D} + \sum_{j=0}^{n} \frac{\mathrm{CF_i}}{(1 + \mathrm{IRR})^{j}} \quad (2)$$

The IRR is widely accepted and used in the appraisal of projects because it is an indicator of the project's expected return of profitability. The IRR is easily compared with the banking worth rates or the cost of the funds used to finance the project. In this study we apply the calculations previously defined to a standard PV installation. For the estimations we take into account different scenarios depending on the feed-in tariff that establish the legislation in force in Côte d'Ivoire [9]. For the remainder variables affecting to the PV plant it is applied market criteria.

3. Primary results and discussion

3-1. Cash Flow for PV Energy Plants

As mentioned before the cash flows are the difference between inflows and outflows***. Table 4*** shows the inflows and outflows that affect cash flows over the 25 years life of the investment. Other variables affecting the cash flow during 25 years of lifespan for the above mentioned PV solar plant are also shown in Table IV. At the time of investment (year 0) only occurs as outflow the capital outlay. After installation, production and sale of energy begins, as well as expenses. The annual production in kWh in our PV plant the first year is 34.100 kWh. The inflows obtained for this production are 2.864.400 CFA, with a tariff for the kWh of 84 CFA. Expenses have been considered as 11% of incomes. These expenses take into account the insurance (6%), taxes for access to the grid (2%), and general maintenance, cleaning electrical wires, etc. (3%). The percentage used for insurance and maintenance are typical values in Europe while the tax to access the electric network depends on the policy of every country.

Here we consider that a tax of 2 % would allow the dissemination of renewable energies and seems sufficient to ensure a correct conservation of the electric network. For the first year the amount for outflows are 315.084 CFA. As mentioned before the difference between inflows and outflows are cash flow, in first year of the investment the cash flow are 17.925.624 CFA. As all machinery, a PV plant is degraded over time and it loses its productive capacity. According to indications of manufacturers of solar PV systems, the annual degradation produces 0,5% loss in the production of electricity. This degradation factor is taken into account in the calculations of the annually production of energy. The electric tariff at year 0 is the present cost of electric energy in Côte d'Ivoire for the common use of families and small companies [9]. In the following years the electric tariff has been increased by the inflation rate corresponding to 2013 (2.81 %) in Cote d'Ivoire according to the data published by the World Bank [10]. The rest of columns in ***Table 4*** show the energy production the total expenses, the annual Cash Flow and the accumulated cash flow for a 20 kW solar PV plant located in Kétesso (Côte d'Ivoire) during its expected life of 25 years [11].

Figure 2 shows the Net Present Value for 20 kW solar PV plants working under the irradiation conditions and expected climatic data of Kétesso (Côte d'Ivoire). The NPV is calculated using equation 1 for several discount rates ranging from 1% to 25 %. As expected, with low discount rates a positive value of NPV is obtained. For discount rate between 1 to 15.82 %, the NPV reaches positive values, which means that the PV installation provides net benefits to the investor. For higher discount rate, the value the NPV is negative, which means that the PV installation would produces losses for investors, so in that condition the investment should not be implemented. The NPV reaches to zero when the discount rate matches the internal rate return (15,82%) on investment ***(equation 2).***

Table 4 : *Cash Flow for a 20 kW PV power plant located in Kétesso (Ivory Coast)*

Cash Flow for a 20 kW PV plant located in Kétesso							
YEAR	**CAPITAL OUTLAY (CFA)**	**Electric Tariff (CFA/kWh)**	**Energy Production (kWh)**	**Energy value (CFA)**	**Total Expenses (CFA)**	**Cash Flow (CFA)**	**Accumulated Cash Flow**
0	17.925.624					-17.925.624	-17.925.624
1		**84,00**	**34.100**	2.864.400	315084	2.549.316	-15.376.308
2		86,360	33.930	2.930.165	323938	2.606.227	-12.770.081
3		88,787	33.760	2.997.440	333041	2.664.400	-10.105.681
4		91,282	33.591	3.066.260	342399	2.723.861	-7.381.820
5		93,847	33.423	3.136.660	352020	2.784.639	-4.597.180
6		96,484	33.256	3.208.676	361912	2.846.764	-1.750.416
7		99,195	33.090	3.282.346	372082	2.910.264	1.159.847
8		101,983	32.924	3.357.707	382537	2.975.169	4.135.017
9		104,848	32.760	3.434.798	393287	3.041.511	7.176.528
10		107,795	32.596	3.513.659	404338	3.109.321	10.285.849
11		110,824	32.433	3.594.331	415700	3.178.631	13.464.480
12		113,938	32.271	3.676.855	427381	3.249.474	16.713.954
13		117,140	32.109	3.761.274	439390	3.321.883	20.035.837
14		120,431	31.949	3.847.631	451737	3.395.893	23.431.730
15		123,815	31.789	3.935.970	464431	3.471.539	26.903.270
16		127,295	31.630	4.026.338	477482	3.548.857	30.452.126
17		130,871	31.472	4.118.781	490899	3.627.882	34.080.008
18		134,549	31.315	4.213.346	504693	3.708.653	37.788.661
19		138,330	31.158	4.310.083	518875	3.791.207	41.579.869
20		142,217	31.002	4.409.040	533455	3.875.584	45.455.453
21		146,213	30.847	4.510.269	548446	3.961.824	49.417.277
22		150,322	30.693	4.613.823	563857	4.049.966	53.467.242
23		154,546	30.540	4.719.754	579701	4.140.053	57.607.295
24		158,889	30.387	4.828.117	595991	4.232.126	61.839.421
25		163,353	30.235	4.938.968	612738	4.326.230	66.165.651
		TOTAL	**803.258**				

The IRR represents the gross profitability on investment. To obtain the net profitability it should consider the cost of capital for investors; and an investor would get net benefits if their cost of capital is below 15.82%. That is, if an economic agent requests a loan to a bank for the capital outlay (17.925.624 CFA) and the annual cost of the loan is 8%, the net investment yield would be 7.82%

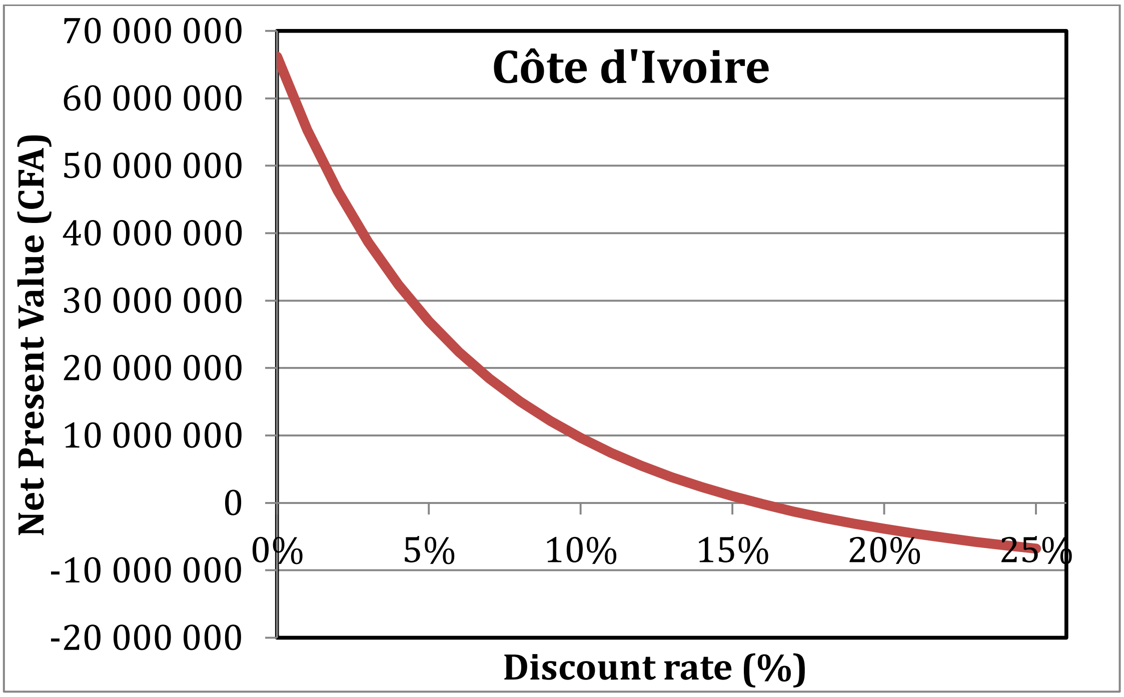

Figure 2 : *Net Present Value for a PV plant with a nominal power of 20 kW located in Kétesso (Côte d'Ivoire) as a function of the discount rate*

The accumulated cash flows for the investment are displayed in ***Figure 3.*** This plot is suitable to graphically assess the Payback time of the investment. Due to the whole cash flows are positive from the first year, the curve have a positive slope. Approximately after six and half years it has recovered the capital outlay. This occurs when the accumulated cash flows curve arrives zero. From this point the curve enters in the positive quadrant because it has been recovered the capital outlay of investment.

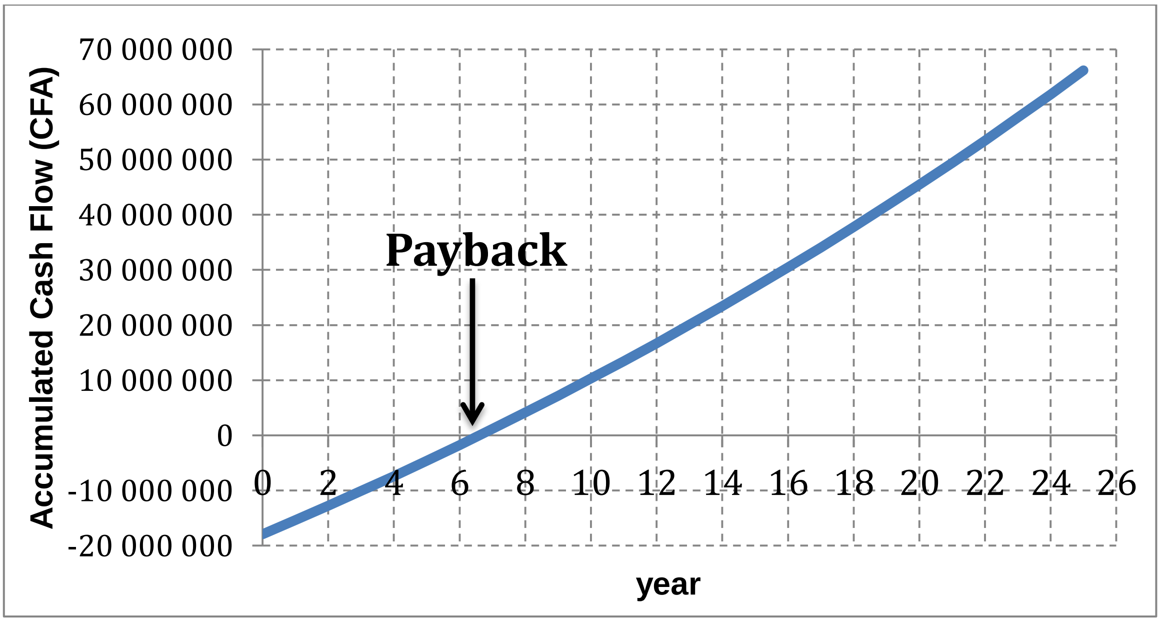

Figure 3 : *Accumulated Cash Flow for a PV plant with a nominal power of 20kW located in Kétesso versus time. The Payback is the time where the accumulated Cash Flow is null. For such a PV solar installation the Payback is slightly longer than 6 years*

3-2. Levelized cost of energy

The Levelized Cost of Energy (LCOE) in an interesting parameter that permits to compare energy costs and energy production. The LCOE is a ratio between the net present value of energy cost and the net present value of energy output. The LCOE is an assessment of the economic lifetime energy cost and lifetime energy production and can be applied to essentially any energy technology and in particular renewable energies. [12]. LCOE is calculated through the following ***equation*** :

$$LCOE = \frac{Capital\ Outlay + \sum_{n=1}^{N} \frac{Expenses_i}{(1+r)^n}}{\sum_{n=1}^{N} \frac{Energy\ Production\ \times (1-DR)^n}{(1+r)^n}} \qquad (3)$$

Where r is the discount rate, DR is the degradation rate, and N is the life of the installation. The LCOE can be seen as the price at which the energy must be sold to break even over the lifetime of the PV technology. It yields a net present value in terms of, for example, CFA per kWh. As mentioned in ***equation (3)*** the LCOE depends of the present discount rate. ***Table 5*** shows the Levelized Cost of Energy for the energy obtained from the formerly defined solar PV installation located in Ivory Coast for different values of the discount rate. A typical value for the discount rate is about 4% and for this value of the discount rate the LCOE for solar PV plant installed in 2015 and operating for 25 years is 47.05 CFA/kWh. It is worth to note that this cost of electric energy obtained from solar PV plants is about 50 % of the present cost of electricity in Ivory Coast. The LCOE takes the value of 84 CFA at a discount rate of 15% and this value agrees with the IRR.

Table 5 : *Levelized Cost of Energy for solar PV production in Côte d'Ivoire in 2014*

Discount rate (%)	LCOE (CFA/kWh)
3	44,14
4	47,05
5	50,09
7	56,47
10	66,61
15	84,14
Electricity Price in Côte d'Ivoire in 2014	84,00

4. Conclusion

The potential for PV plants in Cote d'Ivoire is enormous, but depends on the acquaintance of users of the advantages of this technology from the technological and financial points of view. The production el electric energy from photovoltaic solar plants meets two crucial points; clean energy is generated without any kind of pollution and economic profits are obtained because the production price of the energy is cheaper than other non-renewable sources and the investment can be recovered in a short period of time. This is especially true for Côte d'Ivoire, due to it climate conditions and sun irradiation. In this paper we have calculated the amount of electric energy that can be produced by a 20 kW PV solar plant located in Kétesso. Then, knowing the capital layout required for such installation, the present price of the electric energy in the country and using capital budgeting techniques we have calculated the cash flow generated by the PV installations during the overall expected life time of the installation. For performing these calculations some assumptions have to be done such the evolution of the inflation during the next years, the maintenance expenses and network taxes, which have been fixed to 11% of the production and the drop of energy production due to the aging of the installation what has been set to 0.5%.

From the cash flow data per year we have obtained the Net Present Value for different discount rates and hence we calculate the Internal Rate of Return what is related to the expected profitability in terms of returns of the investment. The calculated IRR for the 20 kW PV installation located in Kétesso is 15.2 %, which is a significant profit in terms of investment returns. Plotting the accumulated cash flow versus time allows the computation of the Payback, which is about 6.3 years. Further, the levelized cost of the energy, which is an estimation of the average cost of the energy produced by the PV plant during all it expected lifetime, has also been calculated for different discount rates. Considering a standard discount rate of 3%, like in most Europe countries, the LCOE is about 44 CFA/kWh, which is close to 50% lower than the present price of electric energy in the country.Investments in PV solar plants have low risk because the investment is mainly released in the beginning, the reliability of related technology is guarantee for 25 years and the raw materials (Sun irradiation) are assured at zero cost. In Côte d'Ivoire a small size PV plant of 20kW is able to produce clean electric energy at a reduced cost during the overall lifetime of the PV plant.

References

[1] - J. E. PAYNE 'Survey of the international evidence on the causal relationship between energy consumption and growth', Journal of Economic Studies, Vol. 37, No 10, pp. 53-95 (2010).

[2] - RENEWABLES 2014. Global Status Report Energy; http://www.ren21.net/Portals/0/documents/e-paper/GSR2014KF/index.html#/2

[3] - I. GUAITA-PRADAS, B. MARÍ SOUCASE; 'Energy Production in PV plants regarded as economic investments. An assessment for PV investments in Germany, Spain and Morocco' IRSEC'14. IEEE Xplore (2015) (In press.)

[4] - http://solargis.info/

[5] - http://photovoltaic-software.com/pvgis.php

[6] - J. JACKSON 'Promoting energy efficiency investments with risk managememnt decision tools' Energy Policy, Vol. 38, pp. 3865-3873 (2010).

[7] - I. GUAITA-PRADAS and B. MARÍ SOUCASE, 'Endorse of renewable energy plants, still an alternative investment in Spain?' SOP Transactions on Economics Research (ER) Scientific Online Publishing, Vol. 1, Num. 2, pp.1-9. (2014) Scientific Online Publishing.

[8] - A.S. SUAREZ SUAREZ, Decisiones óptimas de inversión y financiación en la empresa, Madrid: Ediciones Pirámide (2005).

[9] - http://www.anare.ci/index.php?id=27

[10] - http://datos.bancomundial.org/pais/cote-d%27ivoire

[11] - I. GUAITA-PRADAS, I. BARTUAL-SAN FELIU, B. MARÍ SOUCASE 'Profitability and Sustainability of Photovoltaic Energy Plants in Spain' International Journal of Sustainable Economy (2015) In Press.

[12] - S.B. DARLING, F. YOU, V. VESELKA and A. VELOSA 'Assumptions and the levelized cost of energy for photovoltaics', Energy & Environmental Science, Vol. 4, pp. 3133-3139 (2011).