Original Research Article

Financial Analysis of Photovoltaic Installations in Burkina Faso

ABSTRACT

This article focuses on the economic and financial calculations concerning the production of electrical energy from photovoltaic installations connected to the grid.The estimation ofenergy production is done in fifteen cities in Burkina Faso. Among these localities, ten cities are homes to synoptic stations. The economic return in terms of the return on investment of the electricity production from PV installations is calculated by using the method of budgeted capital. The cost of the energy produced by photovoltaic installations during their operational lives (taken here equal to 25 years) is calculated and compared with other economic parameters. The observation shows that Gaoua records the smallest production and that the highest production is recorded in Ouahigouya. The analysis of the cash flows generated by the operation of these PV installations shows that the profits are perceptible from the 8th year in Ouahigouya and the 9th year in Gaoua. An Internal Rate of Return (IRR) of 14.42% is obtained in the locality of Ouahigouya. For locality of Gaoua the IRR is equal to13.72%. The calculation of Leveled Cost Of Energy (LCOE) gives an average value of 60 Fcfa / kWh for a discount rate of 4%. This value is almost equal to half the average price of electricity in Burkina Faso, which is 119 Fcfa / kWh.

***Keywords** : solar photovoltaic energy, grid connection, capital budgeted, cash flow, average discounted cost of energy*

1. INTRODUCTION

Nowadays, renewable energies occupy a place of choice in the energy mix of many African countries. The use of solar renewable energy especially, is an effective way to fight against global warming, a means for a green economic growth and sustainable development of developing countries **[1-3].**
Photovoltaic (PV) is a sustainable and renewable energy conversion technology that can help to effectively meet the energy needs of a growing world population and reduce the negative impact of the use of fossil fuels **[4-5].** The global share of solar photovoltaic energy has increased significantly (0.26 GW to 16.1 GW) with an annual growth rate ~~of~~ more than 40% between 2000 and 2010 **[6-7-8].**
Although the solar resource is available and free, still the cost of solar installations is not accessible to all. Today, technological innovations allow division of the manufacturing costs by 100, and governments are increasingly encouraging consumers to use this source of energy **[1-6-9-10]** which is clean and environmentally friendly.

Given that, the price of electricity sold to consumers is a function of the price of electricity leaving the plant, an understanding of the feasibility and profitability of the different energy technologies being a paramount for the determination of an energy management policy in a country **[11-12-13].**
As a country with significant solar potential, Burkina Faso enjoys an average of 5.5 kWh/m²/day of sunshine and average solar irradiation duration of 3000 h/year **[14].**
However, the country knows an important energy deficiency. It is obvious that the government alone cannot meet this demand for energy that is growing day by day. The private sector is one of the solutions to this problem. However, the lack of knowledge in solar energy field, the high investment cost and the low demand for energy, especially in rural areas, where need in energy is most pressing does not motivate private investment particularly in Burkina.
In this article, we will try to analyze the profitability of a standard investment in photovoltaic installations in Burkina Faso built for the sale of energy to the National Company of Electricity (SONABEL) by injecting into the grid or off-grid for localities which are not connected to the national grid.

2. MATERIAL AND METHODS

The study is done for fifteen localities in Burkina Faso (**figure 1**). The geographic coordinates (latitude, longitude and altitude) of the various sites are summarized in **Table 1.**

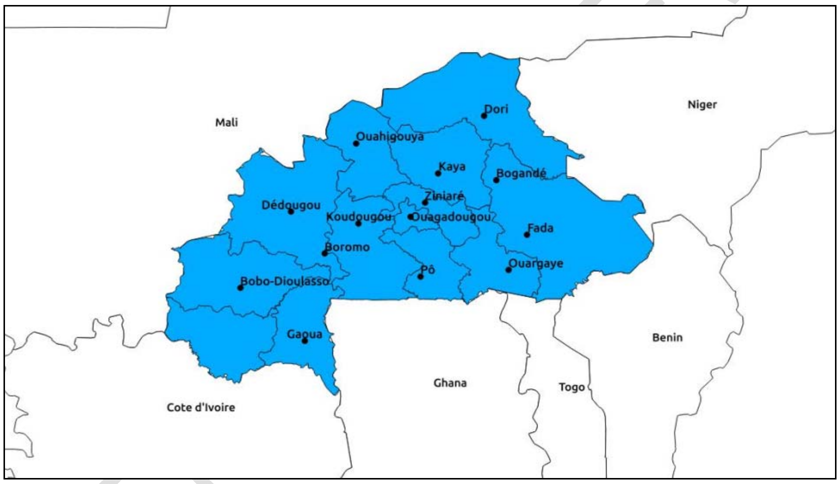

Figure. 1. Location of the sites on the map of Burkina Faso

Table. 1. Geographical coordinates of the sites

Localities	Regions	Latitude (°N)	Longitude (°O,°E)	Altitude (m)
Ouagadougou	Centre	12°21'56''	1°32'O	301
Ouahigouya	Nord	13°34'58''	2°25'17''O	328
Bobo-Dioulasso	Hauts -Bassins	11°10'37''	4°17'52 ''O	425
Boromo	Boucle du Mouhoun	11°44'43''	2°55'48''O	266
Pô	Centre-Sud	11°22'08''	1°22'38''O	299
Fada	Est	12°03'41''	0°21'30''E	302
Gaoua	Sud-Ouest	10°17'57''	3°15'02''O	331
Dori	Sahel	14°02'07''	0°02'04''O	276

Dédougou	Boucle du Mouhoun	12°26’31’’	3°28’14’’O	301
Bogandé	Est	12°58’13’’	0°08’58’’O	275
Koudougou	Centre-Ouest	12°15’04’’	2°22’28’’O	297
Ouargaye	Centre-Est	11°28’36’’	0°02’58’’E	278
Kaya	Centre-Nord	13°05’	1°05’O	326
Ziniaré	Plateau-Central	12°35’	1°18’O	308
Banfora	Cascades	10°37’36’’	4°45’29’’N	285

In order to carry out this study, we had put hypotheses on certain parameters:

- ✓ The study of an installation already done and ready to produce Energy;
- ✓ year 0 being the year of installation conception;
- ✓ the number of hours of sunshine a year;
- ✓ the value of expenses in relation to revenues;
- ✓ the average electric price which varies according to the rate of inflation **[15]** and which is the price compared to the domestic use and small and average companies;
- ✓ the degradation of the installation which plays on its production.
- ✓ etc.

The average cost of kWh for small and medium-sized enterprises and domestic consumption in Burkina Faso is estimated at 119 Fcfa **[16].**
In this work, we performed the simulations for several purchase prices of kWh (as shown in table 2) and for several sizes of installation in W_p to see their influence on the different Parameters of the study.

Table. 2. Calculation elements

Size of PV plant	Electric Tarification	Expenses	Degradation	Inflation
2 to 10 MW_p	60-95Fcfa	11% **[18]**	0.5% **[18]**	2.6**[27]**

The radiation data in the synoptic stations are global averages on the horizontal plane. **Table 3** shows measured radiation values in nine of the ten synoptic stations. In order to take into account the inclination and orientation of the panels we used simulation software.

Table. 3. Mean global horizontal radiation measured in synoptic stations

Localities	Irradiation (kWh/m^2/year)(Météo)	measuring period
Ouagadougou	2168	1976-2016
Ouahigouya	2193	1982-1993
Bobo-Dioulasso	2201	1976-1990
Boromo	2184	1985-2005
Pô	2141	1985-1994
Fada	2309	1976-1992
Gaoua	2147	1976-2002
Dori	2434	1976-1996

Dédougou	2168	1986-1993
Bogandé	-	-
Koudougou	-	-
Ouargaye	-	-
Kaya	-	-
Ziniaré	-	-
Banfora	-	-

Plant productivity is estimated using PVGis photovoltaic productivity simulation software, which provides annual average irradiation by optimizing tilt and orientation **[17].**
Burkina Faso being in the northern hemisphere, the optimal orientation of the modules is taken south. The optimal inclinations provided by the software are shown in **Table 4.**

Table.4.values of the global solar irradiation of the different sites

Localities	Irradiation ($kWh/m^2/year$) (Pvgis)	Optimal Inclinaison (°)	Number of hours equivalent (h)
Ouagadougou	2260	15	2260
Ouahigouya	2300	16	2300
Bobo-Dioulasso	2200	15	2200
Boromo	2240	15	2210
Pô	2220	14	2220
Fada	2230	15	2230
Gaoua	2190	14	2190
Dori	2300	17	2300
Dédougou	2260	15	2260
Bogandé	2270	16	2270
Koudougou	2270	15	2270
Ouargaye	2210	15	2210
Kaya	2280	16	2280
Ziniaré	2260	15	2260
Banfora	2200	14	2200

For these localities, the averages of inclination, global irradiation and the equivalent number of hours are respectively estimated in deg °, kWh/m²/year and hour for a south orientation (Table 4).Table 5 shows in detail the estimated cost of a 2 MWp installation according to the different elements (modules, supports, inverters, labor, insurance, maintenance, etc.).

Table. 5. Estimated cost of 2MWp installation

Designation	Price (Fcfa)

Module, supports	960 000 000
Inverters, cables, substation	800 000 000
Network connection	250 000 000
Project study, works control, labor	95 000 000
Insurance	10 000 000
Total	**2 115 000 422**

Cash flow is the sum of all cash inflows and outflows in a company **[5-6].** Studies have shown that the cost of a PV plant as well as its investment profitability can be determined from the study of cash flow. GUAITA-PRADAS et al. have determined the return on investment of a PV plant (20 kWp) coupled to the grid in the locality of Ketesso in “Côte d'Ivoire”. **[18].**

Several parameters are important for this study. Those are:

2.1 Net Present Value (NPV)

NPV is the difference between the value of revenues and the expenses incurred in an investment. It provides an estimation of the net financial benefit to the investor if the investment is undertaken [21]. A positive NPV value means that the investor's financial situation will improve if the project moves forward. Likewise a negative NPV value indicates a financial loss.

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

Where D is the down payment, *i*is the interest rate, and n is the lifespan of the installation. Despite the fact that the NPV is easy to use, because it is an intuitive tool, it presents limitations in evaluating the profitability of an installation, since it does not distinguish a project with capital expenditures and costs, and offers no indication of the extent of the effort needed to achieve the results.

2.2 Repayment or payback (PB)

The profitability of an investment can be analyzed from its repayment (PB) which is the number of years needed to recover the initial investment. PB is evaluated by adding the cash flow values throughout the life of the installation.

2.3 The internal rate of return (TRI) or IRR

The TRI is widely used in project appraisal as it is an indicator of the expected return of profitability. It is compared to the bank interest rate or the cost of funds used to finance a project. An investment project will generally be retained only if its predictable TRI is sufficiently higher than the bank interest rate **[18-19].** Another highly indicative and accepted parameter in the evaluation of an investment's profitability is the IRR. IRR is a reduction in the investment value, and can be easily compared to the interest rates of a loan taken in a bank. The IRR is also defined as the interest rate that equals the NPV of a series of cash flows to zero. Mathematically, he satisfies the equation:

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

2.4 Leveled Cost Of Energy (LCOE)

The LCOE methodology is a benchmarking or ranking tool for evaluating the cost effectiveness of different energy production technologies. The Leveled Cost Of Energy (LCOE) is an important parameter that compares energy costs and the full cost of energy production for a given system. Since LCOE is a calibration tool, there is a great deal of sensitivity to the assumptions used, especially when the lifepan of the installation is extrapolated several years into the future **[20-22].** It therefore theoretically takes into account all the costs related to the installation and this for all its life-time. These are:

- acquisition of land cost, construction cost, renovation cost of the system, initial investments cost, repayment of loans costs and financial expenses;
- maintenance cost, labor cost and material cost;
- cost of buying fuel (zero in the case of renewable energy, for example for a wind turbine, a PV installation);
- additional costs such as the costs of decommissioning of the facilities at the end of the life, the costs of the tone of CO_2 produced (if it is marketable in a market), etc. **[21-23]**

The costs and the generated electricity may vary according to the location, the production capacity, the complexity of the installation, the efficiency of the installation and the life of the power plant **[5-24].**
The LCOE can be defined as the ratio between the sum of costs and the value of energy production over the life of the project (of the facility) and can be applied to virtually all technologies of Energy especially renewable energies **[25-26].** It is calculated using the following equation:

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

n, C_t, E_t, r are successively the life of the installation, all costs, net annual energy production and the annual discount rate.

3. RESULTS AND DISCUSSION

Note that simulations were carried out for the different localities mentioned in **table 4**. The results obtained show that the lowest production is recorded in Gaoua and the more important is registered in Ouahigouya. Figure 1 below shows the energy productions of the 1st year and the 25th year.
In view therefore of the results of figure 2, we will focus our study on the localities of Ouahigouya and Gaoua. In order to evaluate the influence of the size of the installation and the purchase price of the kWh on the various parameters studied, we have made the simulations for several sizes and prices.

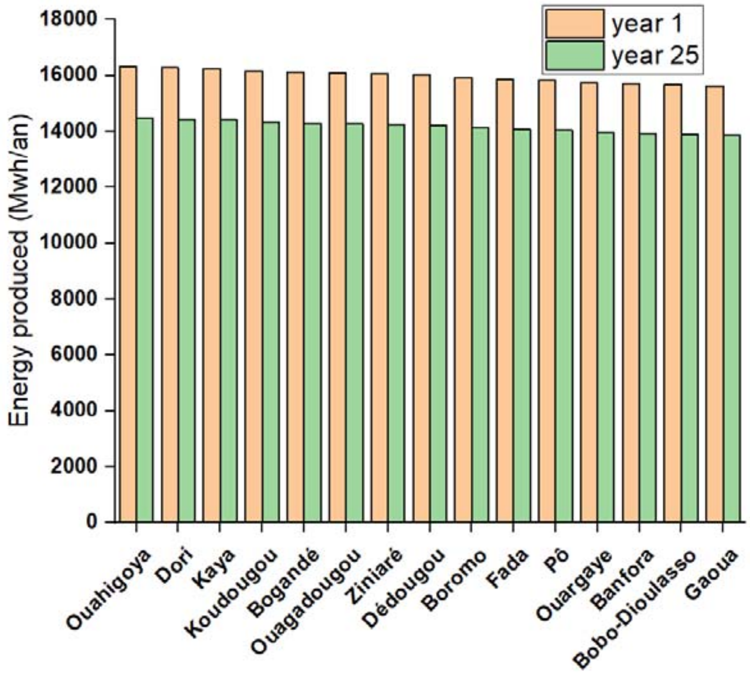

Figure. 2. Energy produced in the 1st and the 25th year for a 10 MWp installation.

Overall, production fell by around 11.5% from the first year to the 25th year.

3.1 Cash flow in the different regions

At the time of investment (year 0) occurs only a money outflow. After installation, the energy production, the sale and expenses start in year 1 supposed as the beginning year of energy production. Expenditures were estimated equal to 11% of revenues generated by the sale of energy produced **[18].** It takes into account insurance, general maintenance, cleaning of electrical wires, etc. Just like the energy produced, the revenues and expenses depend on the size of the PV plant.
Accumulated cash flows allow to evaluate the return of the investment

3.1.1 Influence of the size of the installation on the return on investment time

Tables 6 and 7 show the cumulative cash flow of PV installation in the cities of Ouahigouya and Gaoua for different sizes, the purchase price of the kWh taken equal to 90Fcfa. The tables show that whatever the size of the installation is, the return on investment takes place around 7.5 years after in Ouahigouya and 8 years later in Gaoua. Thus, the size of the facility does not affect the recovery time of the investment.

Table. 6. Cumulative Cash Flow of Facilities in Ouahigouya for Different Sizes

Year	10kWc	50kWc	100kWc	500kWc	1000kWc	2000kWc	4000kWc	6000kWc	8000kWc	10000kWc
0	-10575002	-52875010	-105750021	-528750106	-1057500211	-2115000422	-4230000829	-6345001243	-8460001657	-1,0575E+10
1	-9266969	-46334845	-92669691	-463348456	-926696911	-1853393822	-3706787629	-5560181443	-7413575257	-9266969110
2	-7931637,35	-39658186,8	-79316374,5	-396581874	-793163746	-1586327492	-3172654970	-4758982454	-6345309938	-7931637461
3	-6568437,33	-32842186,7	-65684374,3	-328421873	-656843744	-1313687488	-2627374961	-3941062442	-5254749922	-6568437441
4	-5176787,33	-25883936,6	-51767874,3	-258839372	-517678744	-1035357487	-2070714960	-3106072439	-4141429918	-5176787436
5	-3756093,59	-18780467,9	-37560936,9	-187804685	-375609370	-751218739	-1502437463	-2253656195	-3004874926	-3756093696
6	-2305749,97	-11528749,8	-23057500,7	-115287504	-230575008	-461150016	-922300016	-1383450024	-1844600031	-2305750078
7	-825137,678	-4125688,39	-8251377,78	-41256889,9	-82513778,8	-165027558	-330055100	-495082650	-660110199	-825137788
8	686374,991	3431874,95	6863748,91	34318743,5	68637488,1	137274976	274549967	411824951	549099936	686374881
9	2229432,93	11147164,6	22294328,3	111471640	222943282	445886564	891773142	1337659714	1783546286	2229432819
10	3804694,49	19023472,4	38046943,9	190234718	380469438	760938875	1521877765	2282816648	3043755531	3804694375
11	5412831,75	27064158,8	54128316,5	270641582	541283164	1082566328	2165132671	3247699008	4330265344	5412831641
12	7054530,84	35272654,2	70545307,4	352726536	705453073	1410906146	2821812308	4232718462	5643624616	7054530732
13	8730492,19	43652461	87304920,9	436524604	873049208	1746098416	3492196848	5238295272	6984393697	8730492082
14	10441430,9	52207154,3	104414308	522071537	1044143075	2088286149	4176572313	6264858470	8353144628	1,0441E+10
15	12188076,8	60940384	121880767	609403834	1218807670	2437615340	4875230695	7312846043	9750461391	1,2188E+10
16	13971175,3	69855876,3	139711752	698558757	1397117515	2794235031	5588470077	8382705115	1,1177E+10	1,3971E+10
17	15791487	78957434,9	157914869	789574343	1579148687	3158297375	6316594764	9474892147	1,2633E+10	1,5791E+10
18	17649788,6	88248943	176497885	882489424	1764978850	3529957700	7059915414	1,059E+10	1,412E+10	1,765E+10
19	19546873	97734364,9	195468729	977343643	1954687288	3909374576	7818749167	1,1728E+10	1,5637E+10	1,9547E+10
20	21483549,5	107417748	214835494	1074177470	2148354941	4296709882	8593419779	1,289E+10	1,7187E+10	2,1484E+10
21	23460644,5	117303222	234606444	1173032218	2346064438	4692128876	9384257767	1,4076E+10	1,8769E+10	2,3461E+10
22	25479001,4	127395007	254790013	1273950066	2547900132	5095800264	1,0192E+10	1,5287E+10	2,0383E+10	2,5479E+10
23	27539481,5	137697407	275394814	1376974068	2753948137	5507896275	1,1016E+10	1,6524E+10	2,2032E+10	2,7539E+10
24	29642963,8	148214819	296429637	1482148182	2964296364	5928592729	1,1857E+10	1,7786E+10	2,3714E+10	2,9643E+10
25	31790345,7	158951728	317903456	1589517279	3179034559	6358069118	1,2716E+10	1,9074E+10	2,5432E+10	3,179E+10

Table. 7. Cumulative Cash Flow of Facilities in Gaoua for Different Sizes

Year	10kWc	50kWc	100kWc	500kWc	1000kWc	2000kWc	4000kWc	6000kWc	8000kWc	10000kWc
0	-10575002	-52875010	-105750021	-528750106	-1057500211	-2115000422	-4230000829	-6345001243	-8460001657	-1,0575E+10
1	-9322478,3	-46612551,7	-93225104,4	-466125523	-932251045	-1864502090	-3729004165	-5593506247	-7458008329	-9322510450
2	-8043814,43	-40219395,9	-80438792,8	-402193965	-804387929	-1608775858	-3217551701	-4826327550	-6435103400	-8043879289
3	-6738464,85	-33692814,9	-67385630,9	-336928155	-673856310	-1347712619	-2695425223	-4043137834	-5390850446	-6738563096
4	-5405872,62	-27030024,2	-54060049,4	-270300248	-540600495	-1081200991	-2162401966	-3243602949	-4324803932	-5406004954
5	-4045469,19	-20228181,1	-40456363,1	-202281817	-404563632	-809127265	-1618254514	-2427381771	-3236509027	-4045636323
6	-2656674,14	-13284383,4	-26568767,9	-132843840	-265687680	-531375360	-1062750705	-1594126056	-2125501408	-2656876799
7	-1238894,93	-6195668,77	-12391338,5	-61956693,7	-123913386	-247826773	-495653530	-743480295	-991307060	-1239133864
8	208473,322	1040987,38	2081973,77	10409867,8	20819736,7	41639473,3	83278961,6	124918443	166557924	208197367
9	1686048,15	8428672,55	16857344,1	84286719,5	168573440	337146880	674293775	1011440663	1348587551	1685734400
10	3194459,97	15970538,7	31941076,4	159705381	319410763	638821526	1277643067	1916464601	2555286136	3194107631
11	4734352,34	23669803,6	47339606,2	236698030	473396061	946792122	1893584259	2840376390	3787168520	4733960611
12	6306382,26	31529752,2	63059503,3	315297516	630595032	1261190065	2522380144	3783570217	5044760289	6305950323
13	7911220,45	39553737,9	79107474,7	395537373	791074746	1582149492	3164298999	4746448499	6328597999	7910747460
14	9549551,62	47745184,1	95490367,2	477451835	954903671	1909807343	3819614700	5729422051	7639229402	9549036714
15	11222074,8	56107585,9	112215171	561075853	1122151706	2244303413	4488606841	6732910261	8977213682	1,1222E+10
16	12929503,4	64644510,9	129289021	646445103	1292890208	2585780416	5171560847	7757341270	1,0343E+10	1,2929E+10
17	14672566,2	73359601,6	146719202	733596010	1467192022	2934384044	5868768103	8803152155	1,1738E+10	1,4672E+10
18	16452006,6	82256576,3	164513152	822565757	1645131515	3290263030	6580526074	9870789112	1,3161E+10	1,6451E+10
19	18268584	91339230,8	182678461	913392302	1826784605	3653569210	7307138435	1,0961E+10	1,4614E+10	1,8268E+10
20	20123073,3	100611440	201222880	1006114397	2012228795	4024457590	8048915195	1,2073E+10	1,6098E+10	2,0122E+10
21	22016265,9	110077161	220154321	1100771602	2201543205	4403086411	8806172837	1,3209E+10	1,7612E+10	2,2015E+10
22	23948969,3	119740431	239480861	1197404303	2394808608	4789617215	9579234445	1,4369E+10	1,9158E+10	2,3948E+10
23	25922008,3	129605373	259210746	1296053729	2592107459	5184214917	1,0368E+10	1,5553E+10	2,0737E+10	2,5921E+10
24	27936224,6	139676197	279352394	1396761968	2793523937	5587047873	1,1174E+10	1,6761E+10	2,2348E+10	2,7935E+10
25	29992477,6	149957199	299914398	1499571988	2999143977	5998287953	1,1997E+10	1,7995E+10	2,3993E+10	2,9991E+10

3.1.2 Influence of the purchase price on the return on investment

In this part, the size of the installation is fixed to 10 MWp for a purchase price of the kWh ranging from 60 to 95Fcfa. After the simulations, we found that the time of return on investment of the installations in the 13 regions takes place between the 7th year (95Fcfa / kWh) and the 12th year (60Fcfa / kWh). Figure 3 shows the return on investment for an installation of 10MWp for a purchase price ranging from 60 to 95 Fcfa in the localities of Ouahigouya and Gaoua. The return on investment therefore depends very strongly on the selling price of kWh. The higher the price of kWh is, the faster the return on investment is.

We note here that for the same installation and for any price of purchase of kWh, the return on investment in the city of Ouahigouya comes earlier compared to the city of Gaoua. This is explained by the solar potential and climatic conditions that prevail in the localities. The return on investment in the locality of Gaoua happened around six month little later.

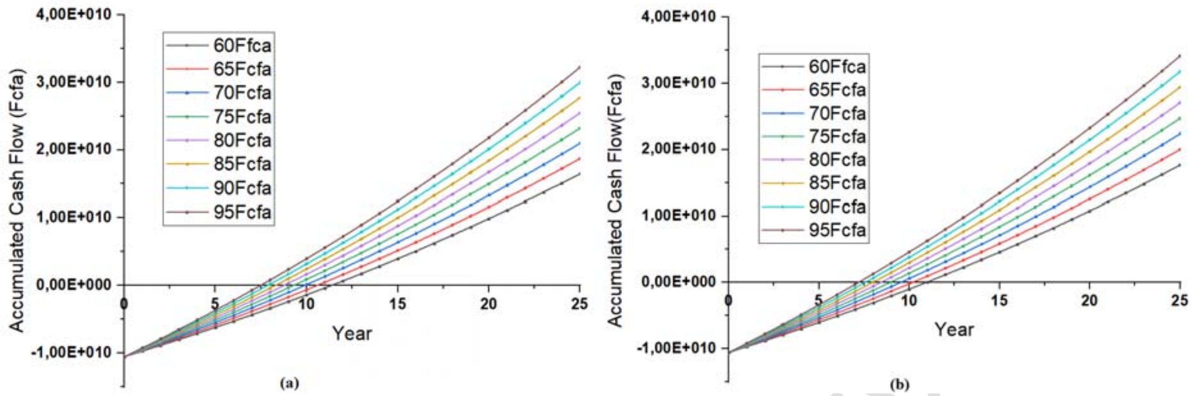

Figure. 3. Accumulated flux at Gaoua (a) and Ouahigouya (b) for different purchase prices per kWh ((a) -60 Fcfa- (h) -95 Fcfa)

Figure 4 shows the accumulated cash flows for a 10MWp installation with a purchase price of 90 Fcfa / kWh in the cities of Ouahigouya and Gaoua. It can be seen that the capital invested is recovered respectively around 7 ½ years after in Ouahigouya and around 8 years later in Gaoua. The benefits are felt therefore from the 8th year in Ouahigouya and the 9th year in Gaoua.

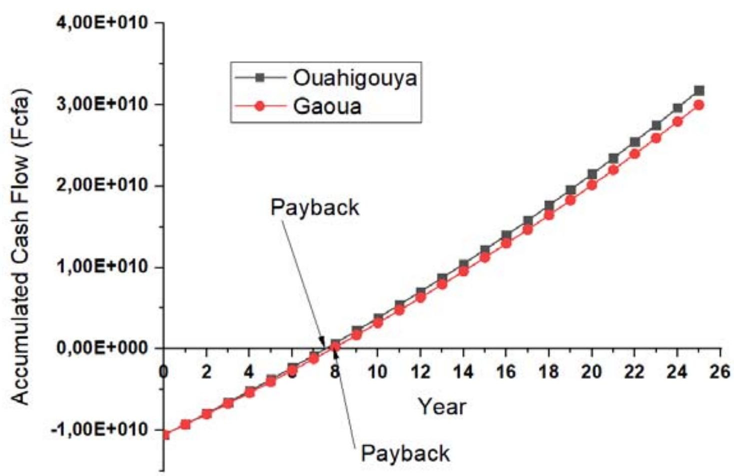

Figure. 4. Cash flow accumulated for a 10MWc installation with a purchase price of 90 Fcfa / kWh in the cities of Ouahigouya and Gaoua.

Table 8 shows the production of electricity in kWh, the inputs and outputs (the expenses) in a power plant of 10Wp according to the electric pricing in the localities of Ouahigouya and Gaoua on the lifespan of facilities that is taken on average equal to 25 years **[18].**
We can also see the electrical pricing that changes because of inflation and the energy produced per year. The first year for a purchase price of 90 Fcfa/kWh, the amount of outflows is 161 667 000 Fcfa for Ouahigouya and 154 802 340 Fcfa for Gaoua. Taking into account that the PV plant is degraded over time

and loses its production capacity **[18-27],** Figure 5 shows the production of a 10 MWp installation in Ouahigouya (black curve) and Gaoua (red curve) depending on the year. We notice that the production decreased with the year. In the first year of the investment, the cash flow amounts are 1 308 033 000 Fcfa for the installation in Ouahigouya and 1 252 491 660 Fcfa for the Gaoua plant.

Table. 8. Electric Tarif (ET), Energy Production (PE), Inputs (EV) and Total Expenditures (TE) in Ouahigouya and Gaoua

		Ouahigouya			Gaoua		
Year	ET(Fcfa/kWh)	EP(kWh)	EV (Fcfa)	TE (Fcfa)	EP(kWh)	EV (Fcfa)	TE (Fcfa)
0							
1	90	16330000	1469700000	161667000	15636600	1407294000	154802340
2	92,34	16248350	1500372639	165040990	15558417	1436664226	158033065
3	94,74084	16167108,3	1531685416	168485396	15480624,9	1466647408	161331215
4	97,20410184	16086272,7	1563651691	172001686	15403221,8	1497256340	164698197
5	99,73140849	16005841,3	1596285101	175591361	15326205,7	1528504079	168135449
6	102,3244251	15925812,1	1629599571	179255953	15249574,7	1560403960	171644436
7	104,9848602	15846183,1	1663609315	182997025	15173326,8	1592969590	175226655
8	107,7144665	15766952,2	1698328841	186816172	15097460,1	1626214866	178883635
9	110,5150427	15688117,4	1733772964	190715026	15021972,8	1660153970	182616937
10	113,3884338	15609676,8	1769956806	194695249	14946863	1694801383	186428152
11	116,336533	15531628,4	1806895804	198758538	14872128,7	1730171888	190318908
12	119,3612829	15453970,3	1844605720	202906629	14797768	1766280575	194290863
13	122,4646763	15376700,4	1883102641	207141290	14723779,2	1803142851	198345714
14	125,6487578	15299816,9	1922402993	211464329	14650160,3	1840774442	202485189
15	128,9156255	15223317,9	1962523543	215877590	14576909,5	1879191405	206711055
16	132,2674318	15147201,3	2003481410	220382955	14504024,9	1918410129	211025114
17	135,706385	15071465,3	2045294067	224982347	14431504,8	1958447349	215429208
18	139,234751	14996107,9	2087979354	229677729	14359347,3	1999320145	219925216
19	142,8548546	14921127,4	2131555483	234471103	14287550,6	2041045956	224515055
20	146,5690808	14846521,8	2176041046	239364515	14216112,8	2083642585	229200684
21	150,3798769	14772289,1	2221455023	244360052	14145032,2	2127128206	233984103
22	154,2897537	14698427,7	2267816789	249459847	14074307,1	2171521372	238867351
23	158,3012873	14624935,6	2315146125	254666074	14003935,5	2216841023	243852513
24	162,4171208	14551810,9	2363463225	259980955	13933915,9	2263106495	248941714
25	166,6399659	14479051,8	2412788703	265406757	13864246,3	2310337528	254137128

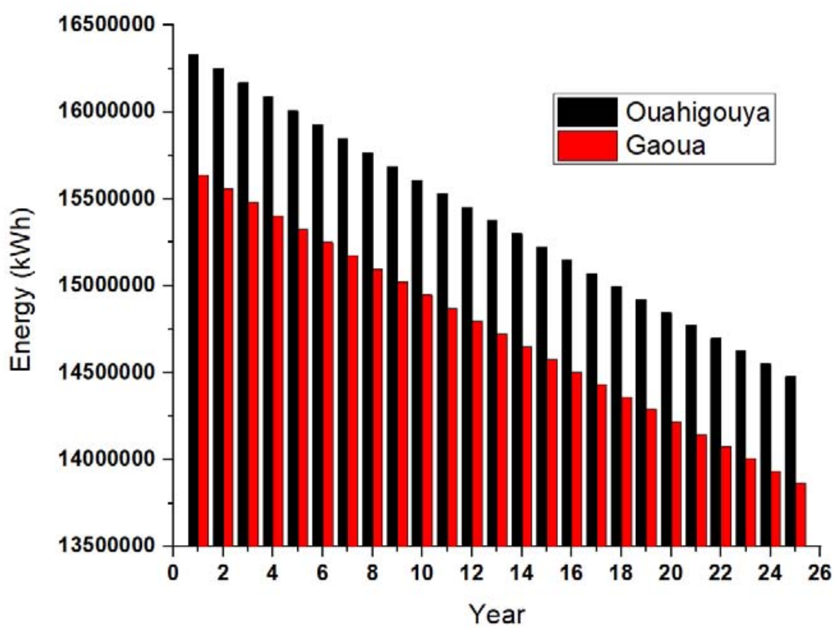

Figure. 5. Generation of electricity during the lifetime of the installation

3.2 Net Present Value (NPV) and Leveled Cost of Energy (LCOE)

Figure 6 shows the net present value (NPV) for solar photovoltaic plants of 10MWp for an electricity pricing of 90 Fcfa / kWh, operating under the climatic conditions of cities of Ouahigouya and Gaoua . The NPV is calculated using equation (1) for several rates ranging from 1% to 25%.

For discount rates between 1 and 14.42%, (black curve) and between 1 and 13.72% (red curve), the NPV in Ouahigouya and Gaoua reaches positive values, which means that the PV installation provides advantages for the investors. For higher discount rates, (> 14.42% for Ouahigouya and > 13.72% for Gaoua) the value of the NPV is negative, which means that the photovoltaic installation would produce losses. The NPV value reaches zero when the discount rate corresponds to an internal yield of 14.42% for the locality of Ouahigouya and 13.72% for Gaoua (equation 2).

As defined in paragraph I.1.3, the IRR is the gross profitability of the investment. To achieve net profitability, the cost of capital must be considered for investors. Investors would obtain net benefits if the cost of their capital is less than 14.42% and 13.72%.

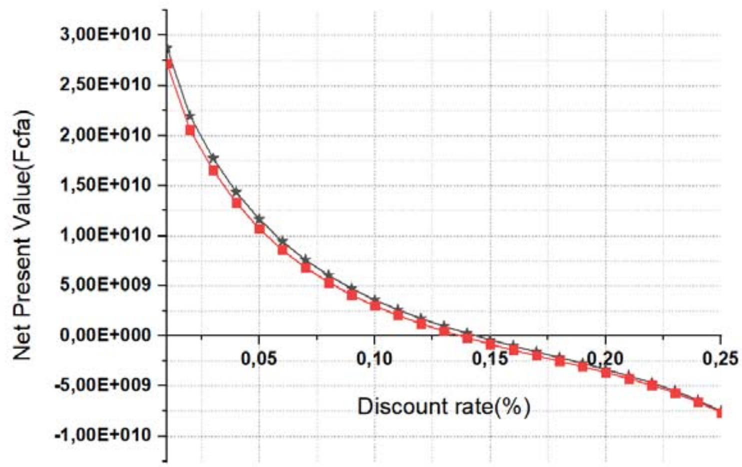

Figure. 6. Net present value of facilities in the localities of Ouahigouya and Gaoua

As indicated in equation (3) in paragraph I.1.4, the LCOE depends on the current discount rate. Table 9 shows the average updated cost of energy produced by solar photovoltaic systems studied for different values of the discount rate. According to REN 21, the average LCOE of photovoltaic production systems decreased by 73% between 2010 and 2017 due to the evolution of technology **[28].**

For a discount rate of 4% (Table 9), LCOE for photovoltaic solar energy from a plant installed in Ouahigouya, operational for 25 years is 59.56 Fcfa / kWh and 61.6 Fcfa / kWh at Gaoua. It is noted that this cost of electrical energy obtained from photovoltaic solar power plants represents around 50% of the current average electricity cost for domestic consumption, little and medium-sized enterprises in Burkina Faso (which is 119 Fcfa). The LCOE in Ouahigouya takes the value 90.038 Fcfa/kWh at a discount rate of 10.06% and 90.037 Fcfa/kWh at Gaoua for a discount rate of 9.46%. Note that these values are in agreement with the IRR (14.42% for Ouahigouya and 13.72% for Gaoua). These values also are in agreement with the average LCOE of PV systems in Africa which is between 50 and 120 Fcfa **[5].**

Table.9. Some values of LCOE for the localities of Ouahigouya and Gaoua

LCOE(Fcfa/kWh)		
Discount rate (%)	Ouahigouya	Gaoua
4%	59,569	61,606
9.46%		90,037
10.06%	90,038	

4. CONCLUSION

In this article, we made a financial profitability study of a PV installation. Using cash flow data per year, we calculated net present value (NPV), internal rate of return (TRI or IRR) related to the expected return in terms of investment returns and evaluated the expected return on investment. We have evaluated the influence of the size of the facility and the purchase price of the kWh on the return on investment. For all the installations studied, we find that the size of the installation does not affect the return on investment. However, the higher the purchases price of kWh, the faster the return on investment. For the two localities studied, an IRR of 14.42% is obtained in Ouahigouya and an IRR of 13.72% is obtained in Gaoua. For a discount rate of 4%, as in most European countries, LCOE is about 59,569 FCFA / kWh in Ouahigouya and 60,61 FCFA / kWh in Gaoua, which is almost 50% less than the current price of energy in Burkina Faso. These values represent a significant benefit in terms of return on investments**.**

The plotting of accumulated cash flow over time made it possible to calculate the total investment payback, which is about 10 years for Ouahigouya and 12 years for Gaoua. This study helps to inform investors in terms of payback and strategic locations for PV investments. The guarantee on the reliability of the PV modules (25 years of life), the free availability of the solar resource makes it possible to perceive that to invest in the photovoltaic installations is low risk and should be encouraged in a country which knows a huge energy deficit. The use of real data for simulations and a study of the influence of climate (humidity for example) over the lifetime of the PV plant will determine the life of PV installations in Africa and particularly in Burkina Faso to improve this work.

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