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Energy production and financial analysis of photovoltaic energy plants in Guinea

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***Abstract*:**

This study investigates the technical and financial viability of photovoltaic (PV) energy systems in Guinea, a country with high solar irradiation, averaging 5.5 kWh/m²/day and over 2,700 hours of sunshine annually. A 50 kWp grid-connected solar PV system located in Koubia is analyzed over a 25-year operational period. The analysis incorporates degradation rates, inflation-adjusted electricity tariffs, and operational costs set at 11% of revenues. First-year energy production is estimated at 82,831 kWh, generating €10,768.03 in revenue and €1,201.55 in expenses, resulting in positive net cash flows from the first year. The system achieves payback in approximately 5 years. Net Present Value (NPV) remains positive for discount rates up to 20.84%, which corresponds to the Internal Rate of Return (IRR). At a 7% discount rate, the Levelized Cost of Energy (LCOE) is calculated to be 0.062 €/kWh, nearly half the current electricity price in Guinea. The results confirm that small-scale PV installations are not only technically feasible but also financially attractive in Guinea. These systems offer a sustainable and low-risk solution to mitigate the country's energy deficit and accelerate its energy transition.

***Keywords* :** Techno-economic analysis ; NPV ; IRR ; LCOE ; Energy policy ; PV investment.

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1 Introduction

Renewable energy now plays a crucial role in the energy mix of many African countries. Solar energy, in particular, represents an effective solution for combating climate change, fostering green economic growth, and supporting sustainable development in developing nations. Photovoltaic (PV) technology, a clean and sustainable energy conversion solution, effectively addresses the growing energy needs of the global population while helping to mitigate the environmental impacts of fossil fuel use. Between 2000 and 2010, the share of photovoltaic solar energy in the global energy mix increased significantly, from 0.26 GW to 16.1 GW, with a remarkable annual growth rate [1–3].

Although solar energy is free and widely available, the cost of solar installations remains high, making it inaccessible to a large portion of the population. However, recent technological advancements have significantly reduced the manufacturing costs of solar equipment, making this energy more affordable, with cost reductions reaching up to 100 times. Additionally, an increasing number of governments are actively promoting the adoption of this clean and environmentally friendly energy source. The price of electricity sold to consumers depends directly on the production costs at the power plant, making it essential to assess the feasibility and profitability of different energy technologies to define an appropriate energy policy [4].

Guinea benefits from high solar irradiation, averaging 5.5 kWh/m^2/day and more than 2,700 hours of sunshine annually, which highlights its strong potential for photovoltaic development. The government alone cannot meet this growing demand. The private sector could play a crucial role in addressing this issue. However, several factors hinder such investments, including a lack of awareness about solar energy, high investment costs, and low demand, particularly in rural areas where energy needs are the most critical [5, 6].

This article aims to analyze the profitability of a standard investment in photovoltaic installations in Guinea, either designed to sell energy to the EDG for grid integration or to provide off-grid electricity to areas not connected to the national grid.

2 Materials and methods

2.1 Experimental area

This study focuses on ten localities distributed across the territory of Guinea. The objective is to design and evaluate the installation of a 50 kWp solar photovoltaic power plant in each of these regions. To this end, the city of Koubia has been selected as the representative site for conducting the detailed case study.

The city of Koubia was selected as the representative site for conducting the detailed case study. This choice is justified by the fact that Koubia presents solar irradiation values and economic conditions close to the average of the ten studied localities, making it a suitable case study. A brief analysis of the variability among these sites shows irradiation levels ranging from X to 5.2 to 5.8 kWh/m^2/day, with minor differences in local electricity tariffs. These elements confirm the representativeness of Koubia in reflecting the broader conditions of the selected regions in Guinea.

To conduct this study, we made assumptions regarding certain parameters:

- The examination of an installation

that has been completed and is prepared to generate energy;

- Year 0 refers to the year the plant was designed;
- The annual number of sunshine hours;
- The proportion of expenses relative to income;
- The average electricity price, which fluctuates with the inflation [7] and applies to residential and small to medium-sized business use;;
- The degradation of the installation, which influences its energy output;
- Etc.

Figure 1 shows the geographical location of the study sites on the map of Guinea. The cost of electricity in Guinea varies depending on the consumer category and the volume of energy consumed. For domestic users, the tariff structure is progressive:

- For the first 40 kWh, the price is 107 GNF/kWh, which is approximately 0.0108 €;
- For consumption between 41 kWh and 330 kWh, the tariff increases to 387 GNF/kWh ≈ 0.039 €;
- For consumption above 330 kWh, the rate is 453 GNF/kWh, equivalent to roughly 0.045 € per kilowatt-hour.

For small and medium-sized enterprises (SMEs) and professional consumers, the tariffs are significantly higher, ranging from 1169 GNF/kWh to 1823 GNF/kWh, which corresponds to 0.12 € to 0.18 € per kWh depending on the type of connection and contracted power [8].

Fig. 1. Location of the study sites on the map of Guinea.

2.2 Energy production in photovoltaic power plants

The main goal of photovoltaic (PV) technology is to convert sunlight into direct current (DC) electricity without relying on chemical reactions or fuels. The generated energy can be stored in batteries or fed into the electrical grid through a device called an inverter, which converts DC electricity into alternating current (AC). Indeed, due to the efficiency of inverters, PV systems can inject AC energy directly into the grid, which facilitates their deployment compared to systems that require batteries. The exact estimation of electricity production depends on complex factors, such as the orientation, angle, and efficiency of the panels, sunlight, temperature, and weather conditions. However, it is possible to estimate energy production using simple methods, considering certain conditions. Electricity production fluctuates due to various factors, such as the available light, the position and tilt of the solar panels, ambient temperature, panel efficiency, and the system's supplied voltage. Although calculating the exact amount of electricity produced by a solar system can often be complex due to rapid changes in conditions, a reasonable estimate of the average production can be made using straightforward techniques.

To maximize energy production, photovoltaic modules must capture the maximum amount of solar photons, and to achieve this, they need to be oriented optimally to collect the most solar radiation. The ideal placement of solar panels depends on the installation location. In the northern hemisphere, panels should face true south, while in the southern hemisphere, they should face true north. Orientation can be easily determined using GPS devices, which are accessible on smartphones. Another important factor is the tilt angle of the panels. Recommendations from specialized research on solar energy suggest that this angle should be close to the latitude of the installation site. Given Guinea's latitude, near the Equator, fixed photovoltaic systems should be tilted between 10 and 13 degrees from the horizontal. Keeping the panels clean, well-oriented toward the sun, and in full sunlight will maximize their performance [9]. However, these systems require solar trackers to maintain the perpendicular orientation of the panels toward the sun. Such systems are already available, but in this example, we focus on fixed photovoltaic modules without solar trackers.

Once the modules are correctly installed, the next step is to determine the amount of solar radiation received by the panels to estimate energy production. This information is available on specialized websites, such as the link [10]. The solar radiation received by a photovoltaic module at a given location can be expressed in terms of power (in watts) or energy (in watt-hours). Several parameters are essential for estimating a module's energy production. Equivalent Solar Hours (ESH) indicate the number of hours per day when the average solar irradiance reaches 1000 W/m^2. For example, if a location receives 4 ESH, it means it has accumulated the equivalent of 4 hours at 1000 W/m^2 per hour, or 4 kWh/m^2, although this radiation may have accumulated at varying rates over a longer period. This concept is useful for easily calculating the electricity production of a photovoltaic system over a given period. To obtain the energy production of a 50 kW photovoltaic system, the simplest method is to multiply the ESH of the location by the peak power of the modules, as specified by the manufacturer. Indeed, all pho-

tovoltaic modules are tested under AM1.5 conditions, which correspond to a solar irradiance of 1 kW/m². Therefore, to estimate the energy production of a photovoltaic system, one only needs to multiply the ESH by the nominal power of the modules.
Technical and economic calculations are provided for a 1 MWc photovoltaic system, suitable for small and medium enterprises as well as households. This system size is chosen for its accessibility. A photovoltaic system can be either grid-connected or off-grid. In the latter case, batteries or another energy storage solution are required. The system described here is grid-connected, allowing the user to utilize the generated energy, inject it into the grid when not needed, or draw energy from the grid when necessary. Grid-connected photovoltaic systems are considered the most efficient for generating, distributing, and using electricity [11,12]. However, using the grid comes with a cost, which will be considered. A photovoltaic system consists of solar panels, and when connected to the grid, an inverter is necessary to convert the DC electricity from the panels into AC electricity for injection into the grid. The nominal power of the system is determined by the inverter's capacity, i.e., 100 kW. However, due to variations in solar irradiance throughout the day, it is common to overdimension the photovoltaic modules by 10%. Standard silicon (Si-PV) modules have a nominal power of 250 W, which means 242 modules are required to achieve a total power of 50 kW. The area occupied by the solar panels in this system is approximately 400 m².
Table 1 provides a summary of the main components used in the photovoltaic installation, including their quantity and associated power ratings for a surface area of 400 m².

Table 1
List of main components and their specifications (Surface 400 m²).

Component	Units	Power (kW)
250 W Si-based PV Modules size: 1675x1000 mm	242	60.5
50 kW Inverter	1	50
Controller	1	-
Metallic structure to hold PV modules	242	-

Among the various semiconductors used for photovoltaic conversion, crystalline silicon is the most common, and the majority of photovoltaic cells and panels are made from it. However, other materials, such as CdTe, CIGS, and TiO2 have reached industrial levels and are now available on the market. Competition in this field aims to increase the efficiency of photovoltaic cells. In this paper, silicon-based solar modules were chosen for their standard nature, but other types of panels are also available. The economic and production considerations described here are independent of the type of module used. The Equivalent Solar Time and estimated energy production for the system are also included. Solar radiation data comes from PVsyst V7.4.8 [13], an online tool that estimates the electricity produced by a photovoltaic system over one year. PVsyst covers Europe, Asia, and Africa and takes into account losses due to reflectance as well as other climatic factors affecting system performance. In the studied example, total losses are estimated to be 19.2%.

2.3 Cost of a 50 kWp PV solar plant

The main manufacturers of photovoltaic modules are China and Germany. Due to international competition among these producers, the cost of a photovoltaic installation remains relatively similar across different regions of the world for the main components, such as modules, inverters, controllers, and mounting systems. Therefore, to calculate the expenses associated with the modules, international prices for a standard installation are used [14, 15]. The cost variation between countries primarily concerns installation labor costs, which have been adjusted according to the rates in Guinea. Table 2 presents the costs associated with a 50 kWp photovoltaic installation, with amounts expressed in GNF. The exchange rate used is 1 € = 9500 GNF. As is often the case in such projects, the majority of the cost (around 80%) comes from solar modules, while labor costs account for only 20% [15, 16].

Table 2
Capital investment for a 50 kWp solar PV system (in euros).

Component	€	€/Wp	%
PV Modules, Inverter, Controller and holders	54,570	1.091	79.6
Installation Labor Cost	13,986	0.279	20.4
Total Cost	68,556	1.370	100.0

2.4 Foundations of the economic study of photovoltaic solar plants

A techno-economic analysis is employed for project cost control, profitability assessments, planning, scheduling, and operational research optimization, among other tasks. For photovoltaic (PV) systems, it is crucial to assess their economic viability so that users can understand their significance and make optimal use of the area under their control. An effective economic analysis can be conducted using cost analysis methods along with cash flow diagrams. Cash flow is defined as the movement of money into and out of a business, and it serves as a primary indicator of the business's financial health [17]. Several capital budgeting criteria must be used to assess the profitability of the investment. Commonly used criteria include Payback Period (PB), Net Present Value (NPV), and Internal Rate of Return (IRR) [18]. PB is the number of years required to recover the initial investment (capital outlay), and it is computed by summing the annual cash flows and estimating the period through this relation. PB analysis offers a straightforward and intuitive decision-making process. However, PB has several well-known limitations as an investment analysis tool, the most significant being its inability to differentiate between short- and long-term investments. NPV, on the other hand, is the difference between the value of income and the expenses incurred from an investment up to the point the investment is made. Thus, NPV provides an estimate of the net financial benefit that would be provided to the organization if the investment is undertaken [19–21]. A positive NPV indicates a positive surplus, suggesting that the investor's financial position will improve if the project proceeds. In contrast, a negative NPV indicates a financial loss.

$$\text{NPV} = -F + \sum_{j=0}^{n} \frac{\text{CF}_j}{(1+i)^j} \tag{1}$$

Where F represents the initial investment, i is the interest rate, n is the lifespan of the technology and CF_i is the annual cash flow at year i, which includes revenues from energy production minus maintenance, insurance, and operational costs. Although NPV is a straightforward and intuitive tool, it also has some drawbacks, particularly regarding: (a) the choice of discount rate for its calculation; a very low interest rate can make an option with benefits that are spread far into the future, appear more profitable than an alternative that generates smaller but quicker profits, when not adjusted for time value; (b) the distinction between projects with varying capital investments and costs, meaning that NPV does not provide insight into the scale of effort required to achieve the projected outcomes. The Internal Rate of Return (IRR) is a discount rate used to assess the profitability of an investment and is defined as the interest rate that makes the NPV of a series of cash flows equal to zero. Mathematically, the IRR satisfies the equation:

$$0 = -F + \sum_{j=0}^{n} \frac{\text{CF}_j}{(1+i)^j} \tag{2}$$

The Internal Rate of Return (IRR) is widely used in project evaluation, as it provides an indicator of the expected return on investment in terms of profitability. It is easily compared to banking interest rates or the cost of funds used to finance the project. In this study, we apply the previously defined calculations to a standard photovoltaic installation. For the estimations, various scenarios are considered based on the feed-in tariff set by the legislation in force in Guinea [22–24]. As for other variables affecting the photovoltaic system, market criteria are applied.

To ensure methodological transparency, the main assumptions used in this study are explicitly justified. The annual degradation rate of 0.5% was adopted in line with values reported by PV manufacturers and previous studies conducted in Sub-Saharan Africa, where long-term performance losses remain within this range. The tariff escalation rate was derived from the historical evolution of electricity prices in Guinea, which have shown a steady upward trend due to inflation and fuel dependency. The operation and maintenance (O&M) costs, estimated at approximately 1.5–2% of the initial investment per year, are consistent with benchmarks used in comparable PV economic assessments in neighbouring countries, such as Burkina Faso and Côte d'Ivoire. These assumptions provide a realistic framework for assessing the financial performance of PV installations in the Guinean context.

3 Results and Discussion

3.1 Cash Flow for PV Energy Plants

As previously mentioned, cash flows are defined as the difference between inflows and outflows. Table 3 presents the inflows and outflows that influence cash flows over the 25-year lifespan of the investment. Other variables impacting the cash flow during the 25 years of operation of the aforementioned PV solar plant are also detailed in Table 3. At the time of investment (year 0), the only outflow is the capital outlay. After installation, energy production and sales begin, along with associated expenses. In the first year, the annual production of the PV plant is 82,831.0 kWh. The inflows generated from this production total 10,768.03 euros, based on a tariff of 0.13 euros per kWh. Expenses are estimated at 11% of income. These include insurance (6%), grid access taxes (2%), and general maintenance, such as cleaning and electrical wiring upkeep (3%). The percentages for insurance and maintenance reflect typical values used in Europe, while the grid access tax varies depending on the national energy policy [25–27]. However, it is important to note that in Guinea these values may vary depending on local conditions, such as labor costs, the availability of spare parts, and the structure of the insurance market. This indicates that while European benchmarks provide a reasonable basis, local adjustments could further refine the analysis.

We assume that a 2% tax would support the dissemination of renewable energy and appears sufficient to ensure proper maintenance of the electrical grid. In the first year, total outflows amount to 1,201.55 euros. As previously mentioned, the cash flow is calculated as the difference between inflows and outflows. For the first year of the investment, the cash flow amounts to 68,556.0 euros. Like all machinery, a photovoltaic (PV) plant undergoes degradation over time, leading to a gradual reduction in its electricity production capacity. According to manufacturers of solar PV systems, this degradation results in an average annual loss of 0.5% in energy output. This degradation factor is incorporated into the calculations of annual energy production. The electricity tariff at year 0 reflects the current cost of electricity in Guinea for typical residential users and small businesses [23,24]. In subsequent years, the tariff is adjusted based on the inflation rate recorded in 2013, which was 7,8% according to data published by the African Development Bank [28]. The remaining columns of Table 3 present the projected annual energy production, total expenses, annual cash flow, and cumulative cash flow for a 50 kWp solar PV plant located in Koubia (Guinea) over its expected 25 years operational lifespan [29].

In this study, a tariff of 0.13 €/kWh was used for cash flow calculations. This value corresponds to the weighted average effective tariff applied by EDG (Électricité de Guinée) to small and medium enterprises (SMEs), which represents the most relevant consumer category for PV electricity injection. Although domestic tariffs in Guinea are progressive, this average tariff was selected as a practical basis for financial modeling. This clarification ensures consistency between the cash flow analysis and the contextual discussion of electricity tariffs in Guinea.

Figure 2 illustrates the Net Present Value (NPV) of a 50 kWp solar PV installation operating under the irradiation and expected climatic conditions of Koubia. The NPV is calculated using Equation (1) for a range of discount rates, from 1% to 70%. As expected, lower discount rates yield a positive NPV, indicating financial viability. Specifically, for discount rates between 1% and 20.84%, the NPV remains positive, suggesting that the investment generates net benefits for the investor. However, for discount rates exceeding 20.84%, the NPV becomes negative, implying that the project would result in financial losses, and under such conditions, the investment should not be pursued. The NPV becomes zero when the discount rate equals the Internal Rate of Return (IRR), which in this case is 20.84%, as defined by Equation (2).

Table 3
Cash Flow for a 50 kWp PV Power Plant Located in Koubia.

Year	Initial Cost (£)	Tariff (£/kWh)	Energy (kWh)	Energy Value (£)	Expenses (£)	Cash Flow (£)	Accumu. Cash Flow (£)
0	68556	–	–	–	–	-68556	-68556
1	–	0.13000	82831	10768.03	1184.48	9583.55	-58972.45
2	–	0.14014	82416.85	11549.90	1216.85	10333.04	-48639.41
3	–	0.15107	82004.76	12388.53	1250.10	11138.43	-37500.98
4	–	0.16285	81594.73	13288.61	1284.27	12004.33	-25496.64
5	–	0.17555	81186.76	14252.91	1319.37	12933.54	-12563.10
6	–	0.18925	80780.83	15287.82	1355.45	13932.38	369.28
7	–	0.20401	80376.95	16397.86	1392.48	15005.39	16374.13
8	–	0.21993	79975.04	17588.51	1430.53	16157.98	32532.11
9	–	0.23708	79575.17	18865.51	1469.63	17395.99	49928.10
10	–	0.25557	79177.29	20235.45	1509.79	18725.66	68653.75
11	–	0.27505	78781.40	21704.74	1551.06	20153.69	88807.44
12	–	0.29699	78387.50	23280.73	1593.45	21687.28	110494.72
13	–	0.32016	77995.56	24971.14	1636.99	23334.14	133828.86
14	–	0.34513	77605.59	26784.29	1681.73	25102.56	158931.42
15	–	0.37205	77217.55	28729.10	1727.70	27001.41	185932.83
16	–	0.40107	76831.47	30815.12	1774.91	29040.21	214973.05
17	–	0.43238	76447.31	33052.61	1823.42	31229.18	246202.23
18	–	0.46608	76065.07	35452.55	1873.26	33579.30	279781.52
19	–	0.50243	75684.74	38026.77	1924.46	36102.31	315883.83
20	–	0.54163	75306.23	40787.09	1977.05	38810.04	354693.87
21	–	0.58387	74929.71	43749.50	2031.08	41718.42	396412.29
22	–	0.62915	74555.15	46926.16	2086.60	44839.56	441251.85
23	–	0.67851	74182.36	50333.46	2143.61	48189.85	489442.15
24	–	0.73143	73811.45	53988.17	2202.20	51785.97	541228.12
25	–	0.78845	73442.39	57908.25	2262.39	55645.86	596874.33

The Internal Rate of Return (IRR) reflects the gross profitability of the investment. To determine the net profitability, one must account for the investor's cost of capital. An investor obtains a net benefit if their cost of capital is below 20.84%. In other words, if an economic agent takes out a bank loan to cover the capital outlay (68556 €) and the annual interest rate is 8%, then the net investment return would be 12.84%.

Figure 3 illustrates the accumulated cash flows associated with the investment. This graph provides a clear visual representation to assess the Payback period of the project. Since cash flows are positive starting from the first year, the curve maintains a consistently positive slope. The capital outlay is fully recovered after approximately five years, this corresponds to the point where the accumulated cash flow curve crosses the zero mark. Beyond this point, the curve enters the positive quadrant, indicating that the initial investment has been entirely recovered.

3.2 Local Specificities in Guinea

The originality of this study lies in the consideration of Guinea's local conditions, which directly influence the competitiveness of photovoltaic (PV) systems. From a technical perspective, the national grid managed by Électricité de Guinée (EDG) is characterized by poor reliability, frequent outages, and limited coverage, particularly in rural areas where the electrification rate barely reaches 20%. In addition, the grid is fragmented into electrical islands, which complicates the integration of large grid-connected PV plants. From a regulatory standpoint, Guinea adopted in 2017 a renewable energy law aimed at encouraging private investments. However, the absence of guaranteed feed-in tariffs still limits the attractiveness of the sector. Moreover, despite some occasional exemptions, taxation on imported PV equipment remains relatively restrictive. In terms of economic and tariff structures, progressive electricity pricing (ranging from 107 to 453 GNF/kWh for households and up to 1823 GNF/kWh for SMEs) makes solar energy particularly competitive compared to conventional sources. These elements highlight that local constraints and opportunities reinforce the relevance of PV deployment in Guinea.

3.3 Comparative Analysis with Other West African Countries

To better situate Guinea in its regional context, it is useful to compare the obtained results with similar studies conducted in other West African countries:

- **Burkina Faso:** A study covering fifteen localities reported a payback period of 8 to 9 years, with an Internal Rate of Return (IRR) ranging from 13.7% (Gaoua) to 14.4% (Ouahigouya). The Levelized Cost of Energy (LCOE) was estimated at 60 Fcfa/kWh, equivalent to approximately 0.091 €/kWh [32].
- **Ivory Coast (Côte d'Ivoire):** The analysis of a 20 kW PV system installed in Kétesso indicated an LCOE of 0.085 €/kWh, a net annual output of 34,100 kWh, and a payback period of about 9 years [33].
- **Guinea (present study):** For a 50 kWp plant in Koubia, the LCOE is 0.062 €/kWh and the IRR reaches 20.8%, with a payback period of approximately 5 years.

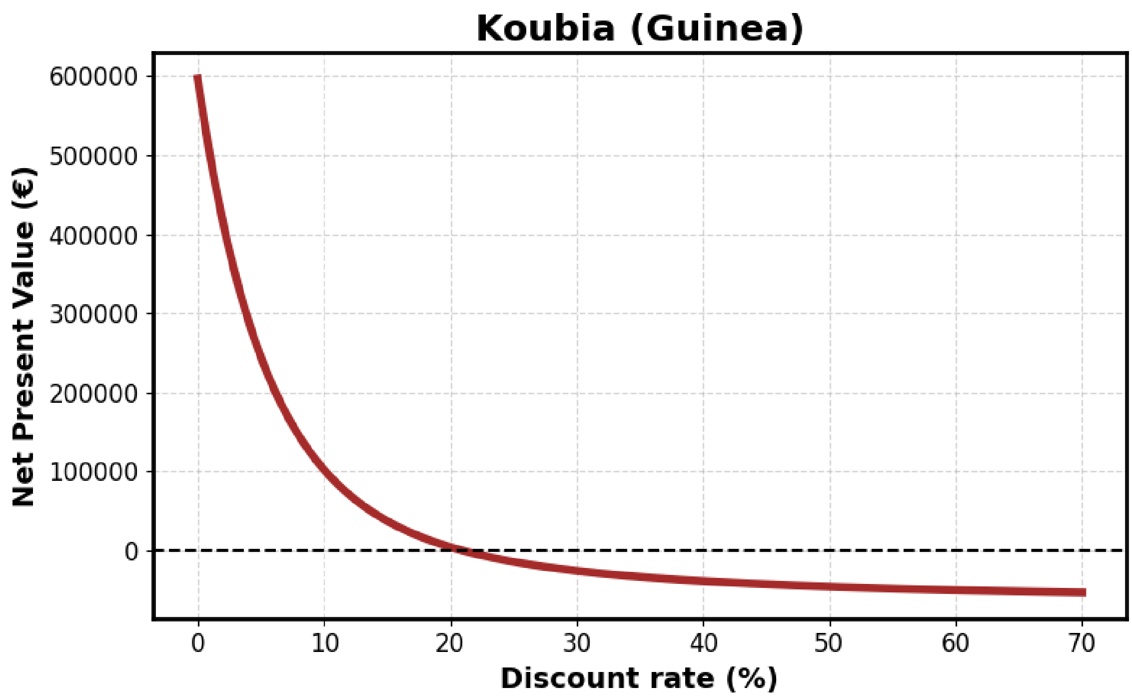

Fig. 2. Net Present Value (NPV) of a PV plant with a nominal capacity of 50 kWp located in Koubia (Guinea) as a function of the discount rate.

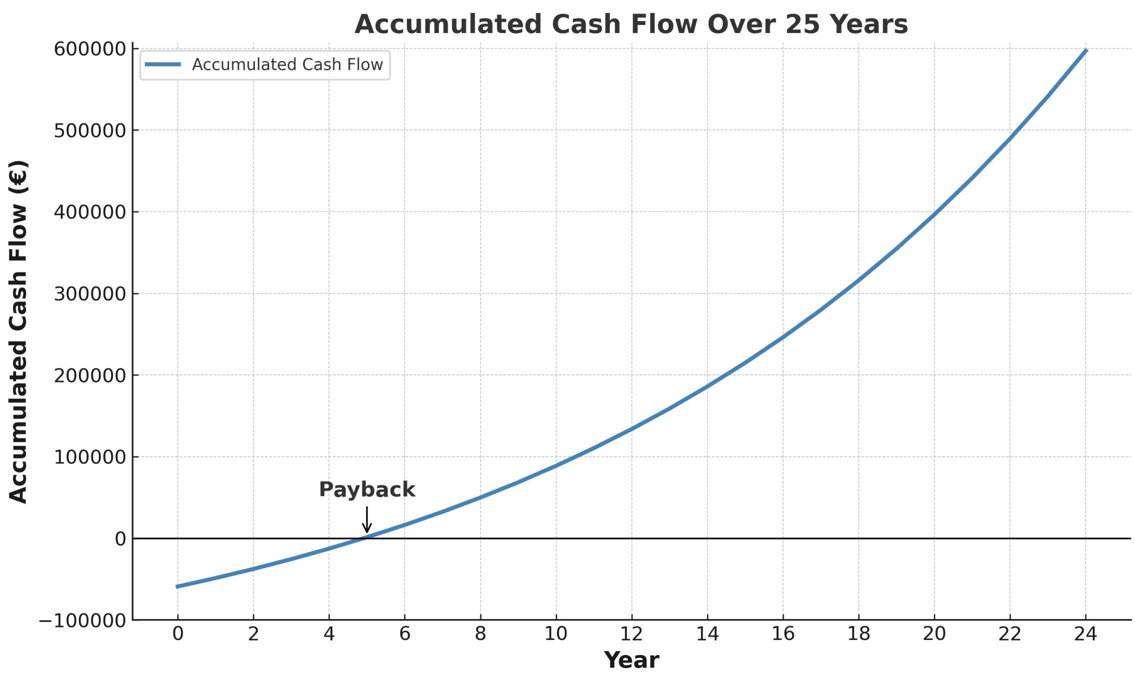

Fig. 3. Accumulated cash flow versus time for a PV plant with a nominal power of 50 kWp located in Koubia. The payback period is defined as the time required for the accumulated cash flow to reach zero. In this specific solar PV installation, the payback period is slightly over five years.

3.4 Levelized Cost of Energy

The Levelized Cost of Energy (LCOE) is a valuable indicator that enables the comparison of energy costs and energy production across different technologies. It is defined as the ratio between the net present value (NPV) of total energy-related costs and the NPV of total energy output over the system's lifetime. The LCOE provides a comprehensive assessment of the cost of energy generation per kilowatt-hour over the operational life of the project. It can be applied to virtually all types of energy systems, particularly renewable energy technologies [30, 31].
The LCOE is calculated using the following equation:

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

Where r denotes the discount rate, DR the degradation rate, and N the operational lifetime of the installation. The Levelized Cost of Energy (LCOE) represents the minimum price at which the electricity generated by a photovoltaic (PV) system must be sold to break even over its lifetime. It provides a net present value of energy generation costs, typically expressed in € per kilowatt-hour (kWh). As described in Equation (3), the LCOE is highly dependent on the selected discount rate. Table 4 presents the calculated LCOE for the previously defined 50 kWp solar PV system located in Guinea, evaluated under varying discount rates. A commonly used discount rate is around 7%. At this rate, the LCOE for a PV plant installed in 2023 and operating over a 25-year period is 0.0062 €/kWh. It is worth noting that this value represents approximately 50% of the current electricity price in Guinea. When the discount rate increases to 15%, the LCOE rises to 0.143 €/kWh, which aligns with the Internal Rate of Return (IRR) of the investment.

Table 4
Capital investment for a 50 kWp solar PV system (in euros).

Component	€	€/W	%
PV Modules, Inverter, Controller and holders	54,570	1.091	79.6
Installation Labor Cost	13,986	0.279	20.4
Total Cost	68,556	1.370	100.0

4 Conclusion

The potential for photovoltaic (PV) energy in Guinea is considerable, particularly given the country's high solar irradiation (averaging 5.5 kWh/m^2/day) and more than 2,700 hours of sunshine annually. However, the development of solar energy strongly depends on raising awareness among users regarding the technological advantages and financial viability of this renewable energy source. This study has analyzed the technical and economic performance of a 50 kWp solar PV plant located in Koubia, Guinea. Based on realistic assumptions, including a 0.5% annual degradation rate, inflation-adjusted electricity prices, and estimated operational expenses fixed at 11% of revenues, we evaluated the plant's energy output, cash flow, and financial metrics over a 25-year lifetime. First-year energy production was estimated at 82,831 kWh, generating revenues of 10,768.03 € ≈ 102,296,285 Guinean francs (GNF), while expenses amounted to

1,201.55 € ≈ 11,314,725 Guinean francs (GNF). The project yields a positive annual cash flow from the first year. Over time, the accumulated cash flow grows consistently, enabling a payback period of approximately 5 years, after which the installation begins to generate net profits. The Net Present Value (NPV) was calculated for various discount rates. A positive NPV is observed for rates up to 20.84%, which is also the Internal Rate of Return (IRR). This IRR represents a highly attractive return, especially in comparison to typical loan interest rates in Guinea, thus confirming the financial viability of the investment. Additionally, the Levelized Cost of Energy (LCOE), which expresses the average cost of energy production over the system's lifetime, was computed. At a standard 7% discount rate, the LCOE was found to be 0.062 €/kWh, or approximately 676.96 GNF/kWh, which is less than half the current electricity price in Guinea (0.143 €/kWh or ≈ 1,572.48 GNF/kWh). Compared to similar studies in Burkina Faso and Côte d'Ivoire, the Guinean case shows more favorable financial indicators (lower LCOE, higher IRR, shorter payback), confirming the strong competitiveness of PV energy in Guinea.
The results demonstrate that small-scale PV installations in Guinea not only contribute to clean energy production but also represent a highly profitable and low-risk investment. The combination of favorable climatic conditions, technological reliability over 25 years, and zero-cost solar resources make PV systems an excellent solution for sustainable and affordable electricity generation in Guinea. The findings of this study are relevant to both investors and public authorities. For investors, the positive financial indicators, such as Net Present Value (NPV) and Internal Rate of Return (IRR) highlight the profitability of PV projects in Guinea.
For policymakers, the results demonstrate the contribution of PV deployment to national energy security and to the achievement of sustainable development objectives. The policy implications are therefore twofold: the need to establish incentive tariffs and to reduce fiscal barriers on PV equipment, while also creating mechanisms that facilitate private sector participation in the energy transition.
This study has focused on the technical and financial performance of PV systems in Guinea. However, we recognize that PV deployment also has important socioeconomic impacts, such as job creation, improved access to electricity, and poverty reduction. These aspects were not included in the present analysis but will be addressed in future work to provide a more comprehensive evaluation of the benefits of PV energy in Guinea.

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