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Research Article

Techno-Economic and Environmental Feasibility Study of a Hybrid Photovoltaic Electrification System in Back-up Mode : A Case Report

Henri Wilfried Hounkpatin[a,b*], Hagninou Elagnon Venance Donnou[a,b], Victorin Kouamy Chegnimonhan[b,c,d], Latifath Inoussa[b], Basile Bruno Kounouhewa[a,d]

[a]*Laboratory of Physics Radiation (LPR), Faculty of Science and Technology (FAST), University of Abomey-Calavi, 01 B.P.526, Cotonou, Benin*

[b]*Centre R&D de Solar and Electrical Energies Power Engineers Group (SEEPEG), Godomey Gare, Abomey-Calavi, 03 B.P. 273, Cotonou, Benin*

[c]*Thermics and Energy Laboratory of Nantes, 44300 rue Christian Pauc, 44300 Nantes, France*

[d]*IRITESE, Benin Center of Research and Innovation (CBRSI), Benin*

Abstract. In developing countries, institutions that have to operate continuously during daylight hours consume relatively large amounts of electrical energy for lighting and air conditioning, leading to high bills. Untimely power cuts lead to a fluctuation in the voltage delivered by the conventional network, which induces the malfunctioning of electrical equipment and the discontinuity of judicial work. The use of photovoltaic solar energy makes it possible, on the one hand, to ensure continuity of service in the event of damage, and on the other hand to stem greenhouse gas emissions through the sustainable nature of this energy. Solar installations also make it possible to maintain the permanent power supply in the event of instability of the electrical network and to correct the voltage variations undergone by the energy equipment. Thus, this (case) study is based on the energy balances evaluated on the buildings of the jurisdiction of the city of Kandi (Benin) to propose effective solutions of electrification according to six (6) technical scenarii. Each component of the back up system has been sized considering technical requirements and an economic and environmental study has been carried out. The results indicate that the integrated scenario 6 of a "back-up" system with a solar fraction of up to 37% (49.5 kWc) seems to be the most suitable conf iguration for the current needs of the Kandi jurisdiction due to the shortest time to return on investment (5.1 years) and the maximum annual savings generated (33,674 USD). The environmental impact study has made it possible to determine the CO_2 emissions avoided as well as the contribution of Carbon credits that this jurisdiction would reap has been evaluated at 115.8 tCO_2 equivalent, or 10.6 hectares of forest carbon preserved over the life of the project. This configuration is therefore strongly recommended for a sustainable energy mix in the jurisdictions of Benin as well as for administrative or similar sites where electricity consumption is maximum during the day.

Keywords: PV solar panel sizing, backup scenario, sustainable development, techo-economic profitability, solar/conventional energy hybridization.

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1. Introduction

Solar energy has improved significantly over the past few decades and has become more affordable. This makes it a useful energy source for developing countries. Solar energy is especially sustainable for these places because it can be used in different places and has a high output efficiency. This makes solar energy a more sustainable renewable energy source. (Shayan *et al.*, 2022; Guno *et a*l., 2021; Fahmi *et al.*, 2016; Na and Byrd 2013) However, most renewable energy sources, especially solar and wind energy, are inherently unstable; therefore, backup power blocks are required to minimize the mismatch between generation and demand from these random resources. Like developing countries, in order to control energy consumption, the Benin government launched the "Energy and Energy Efficiency Control" project. This flagship project of the government action plan aims to end energy-intensive electronics and commercialize new high-performance electronics to obtain more electricity at affordable costs in Benin (Ministère de l'Energie, 2022). To accompany these actions, the Court of First Instance (TPI) of Kandi has decided to embark on this path which will enable it to have an energy system which provides more services while consuming as little energy as possible, thus contributing to the reduction of greenhouse gas emissions related to the operation of occupied buildings. It is all the better when the energy system uses as little energy as possible to produce the requested service, whether it is refrigeration, air conditioning, lighting or any other energy need. Consequently, the idea of using renewable energies seems to be the best alternative to achieve this. Indeed, the Tribunal of Kandi, located in the North of Benin benefits from a beautiful sunshine throughout the year. The implementation of the appropriate energy system requires a technical, economic and environmental feasibility study including the correct sizing of the installation, the cost estimate, the study of the profitability of the photovoltaic installation and its environmental impact.

Several methods and tools are used in the literature to study the technical, economic and environmental feasibility of solar installations. Thus, in the studies of (Benelkadi *et al.* 2019), the authors modeled and estimated the photovoltaic solar resource

* Corresponding author
Email: orestahenrius@gmail.com (H. W. Hounkpatin)

in order to deduce the technical and economic feasibility of photovoltaic power plants in different regions of the Algerian territory. The financial analysis was based on an analytical method of evaluating parameters such as the price per kWh of electricity, the annuity, the recovery factor and the present value of the costs. Sanwogou *et al.* (2019) proposed in their study a photovoltaic solar system to supply the Physics Laboratory of the University of Kara in Togo in order to reduce its electricity bill and solve the problem of untimely power cuts from the Energy Company Electricity of Togo (CEET). This investigation was based on the RETScreen dimensioning tool after defining the adequate load profile and taking into account the real geographical and climatic parameters. (Imam *et al.* 2019) used the System Advisor Model software to carry out a technical-economic feasibility analysis of a grid-connected residential photovoltaic system for a typical apartment in Saudi Arabia, based on various key performance indicators, at namely: efficiency, capacity factor, performance ratio, levelized energy cost, net present value, internal rate of return and payback period. Bourahla *et al.* (2019) analysed the economic impact of photovoltaic energy production by a future campus microgrid for the University of Science and Technology (USTO) in Algeria. The feasibility analysis made it possible to determine the number of years of recovery, the internal rate of return of 5% and the profitability index. This economic analysis shows that the photovoltaic solar system project on the USTO campus can be considered a profitable investment with a substantial financial contribution. Hanen *et al.* (2018) carried out a design and technical-economic evaluation of a grid-connected PV system in the city of Tozeur (Tunisia), with a size of 10 MW. The numerical simulation was carried out using Homer software and an Excel application. According to the authors, this study further enriches the body of knowledge on the feasibility, technical performance and economics of grid-connected solar photovoltaic with different time adjustments. In another study, the examination of the technical-economic feasibility analysis of a photovoltaic (PV) solar energy production was carried out taking into account a photovoltaic power plant with a capacity of 100 kWp as an example, in the province of Adana, Turkey by (Dagtekin *et al.* 2014). The technical characteristics of the photovoltaic generator, the amount of electricity produced, the cost of electricity production, the investment and operating costs, the amortization periods and the amount of CO_2 emission reduced have been determined for the photovoltaic solar power plant. Bermeo *et al.* (2021) carried out the technical and economic feasibility study of a solar power plant on a commercial surface in Azogues in Ecuador. The tools used for the simulation were the Lumion software, an IFC file created and imported into the Solarius PV energy simulator, a software specialized in the design of photovoltaic systems. The size of the photovoltaic system designed, the installed price per watt, the internal rate of return (IRR) and the net present value (NPV) are the technical-economic parameters evaluated by the authors. Solar energy production and economic evaluation are analysed in the work of (Yaniktepe *et al.* 2017), using daily solar radiation and average temperature data which are measured for three years in Osmaniye province in Turkey. The economic values of the study such as Net Present Value (NPV), Internal Rate of Return (IRR), payback year, and simple payback period were evaluated. Osmaniye has proven to be a considerable region for photovoltaic (PV) investment in power generation where investment of a PV is applicable. Hussein and Jasim (2019) assessed the feasibility of building a 10 MW solar PV power plant in Iraq from an economic and environmental perspective. Apart from the economic parameters (discounted energy cost analysis), the cash flows (preventive maintenance, servicing ...) over the life cycle of the power plant and the net present value of the plant were assessed. The authors were also interested in the environmental benefits related to the reduction of greenhouse gas emissions. The analyses then showed that the study region is very promising for solar PV investments. According to Singh and Baredar (2016) hybrid systems combining more renewable energy sources are a reliable and environmentally friendly alternative for electricity generation. In the study by (Vakili *et al.* 2022), the potential use of solar photovoltaic energy, wind turbines and generators in stand-alone and grid-connected hybrid systems was evaluated for a large Italian shipyard using microgrid design optimization software. Net present cost (NPC), discounted cost of energy (LCOE), internal rate of return (IRR) and discounted payback period were considered by the authors as the main optimization objectives. In the village of Dera Ismail Khan district, Pakistan, Ali *et al.* (2021) developed a rural energy system design framework and analyzed the techno-economic feasibility of potential hybrid energy systems (HES) for rural electrification of this locality. System size optimization and techno-economic viability are conducted using a standard HOMER PRO software tool to meet the peak load demand. Gopinath *et al.* (2022) developed an optimal hybrid system for the load profile of Shinas University of Technology and Applied Sciences (UTAS-Shinas). Various hybrid and stand-alone combinations involving renewable and non-renewable options are simulated and analyzed with a hybridization software tool, HOMER Pro. The current cost (NPC), energy cost (COE), payback period and greenhouse gas (GHG) emission control are essentially according to the authors the constraints of the optimization procedure. (Islam *et al.* 2022) evaluated the technical and economic performance of a hybrid renewable energy system for a rural health center in northwest Bangladesh. The state-of-the-art PV design software, HOMER Powering Health Tool, was used to estimate the load requirements and for the techno-economic and environmental evaluation of the microgrid system. (Amupolo *et al.* 2022) investigated different off-grid renewable energy-based electrification schemes for an informal settlement in Windhoek, Namibia. The objective of the study is to find a feasible energy system that satisfies technical and usage constraints at a minimum discounted cost of energy (LCOE) and net present cost (NPC). HOMER Pro software is used for system sizing and optimization. The techno-economic feasibility of installing a 3 kilowatt-peak (kWp) photovoltaic (PV) system in Kathmandu, Nepal was carried out by (Poudyal *et al.* 2021). The technical viability of the designed PV system is then evaluated using PVsyst and Meteonorm simulation software. The discounted energy cost for the system, investment rate, payback period, and CO_2 emission savings over the lifetime of the system were calculated during the study. In a recent study, (Singh and Rizwan 2023) developed an economical and optimal PV/biogas hybrid configuration for power generation for rural communal facilities, including an elementary school and Panchayat Ghar buildings in Sarai Jairam village in Uttar Pradesh, India. The analysis with HOMER produced a solution that included the total net present cost (NPC) and the cost of electricity (COE). These results were then refined with a sensitivity analysis. A techno-economic and environmental analysis of a hybrid renewable energy system for sustainable electrification of the rural area of Al-Dhafrat in Oman was conducted by (Al Abri *et al.* 2023). The Electrical Transient Analyzer Program (ETAP) software is used to evaluate the operational performance of the hybrid system, such as bus voltage profiles and active and reactive power losses. This study revealed that the PV-wind-diesel system is the optimal energy-mix hybrid microgrid for the rural area of Al-Dhafrat in Oman. Further technical, environmental, and economic feasibility studies were conducted for the construction of a 5 kW PV power plant in a city in northern Iran (Sari) using the RETScreen software developed by Natural Resources Canada by

(Semeskandeh *et al.* 2022). The proposed system includes a two-stage multi-chain inverter with ZETA DC-DC converter and a modified P&O algorithm. A techno-economic analysis of a solar photovoltaic mini-grid system for five typical rural communities in Chad while promoting renewable energy system adaptation and rural electrification was presented by (Hassanea *et al.* 2022). The system development costs, electricity tariff, and power generation sizing are then performed by the authors via the discounted cost of electricity (LCOE) technique.

These various works show the interest given by the authors to the technical-economic and environmental feasibility study of a source of solar hybrid or renewable energy production with a view to its use to ensure quality energy autonomy for populations at various levels. The various technical, economic and environmental parameters necessary to properly carry out this studied have been highlighted. Among the software used, RETSreen is the most appropriate and easy-to-use tool for the feasibility analysis of clean energy systems (Sanwogou *et al.* 2019). However no investigation has been conducted to reduce energy shortage in official buildings in Benin, nor to apply hybrid solar and quantify the techno-economical and environmental benefit of such approach. In this article, the technical feasibility study of a hybrid backup system (solar and conventional source) in the jurisdictions of Benin from the RETScreen tool is proposed in order to reduce electricity bills by the control of energy and energy efficiency that accompanies the commissioning of the photovoltaic solar generator. From different power balances which led to considering six (6) energy consumption scenarios, a technical dimensioning of the components of the solar system as well as an economic and environmental evaluation will allow to retain the best option of electrification on the basis of the three criteria.

2. Research Methods

2.1 Presentation of the study area

Kandi is located in northern Benin with an area of 3421 km² at longitude 11°07'43" North and latitude 2°56'13" East. Its Sudano-Sahelian climate is characterized by a rainy season from May to October and a dry season from November to April. This distribution of rainfall is not static because it experiences differences in days in the start of the different seasons over time. The average rainfall is 1000 mm per year. This annual rainfall varies between 850 mm and 1150 mm of water. The temperature is high throughout the year and is between 23°C and 36°C. The relative humidity reaches 80% during the rains, but drops to 35% during the dry season. Harmattan in the dry season and monsoon in the rainy season are the prevailing winds. Figure 1 provides an overview of the study site.

Fig. 1 Geographical location of the city of Kandi in Africa (Google maps)

2.2 Data collection

To record the data, we used:

- The GPS Test application is a reliable android application that consists of five (5) tabs: the first tab is for basic information about a GPS connection, the second tab has the same functions, except that the satellite is represented by a compass, the third tab displays the coordinates on a world map, it tells us what part of the globe we are on, the fourth tab allows us to determine our altitude, the last tab concerns information relating to GMT dates and times, local times and dates as well as sunrise and sunset times.
- Google Earth: It is a software developed by Google + allowing users to browse the earth by satellite images, in 2D or in 3D. It is also possible to carry out research on the various places of a city (restaurants, hotels, etc.) and to consult road routes. It was used to locate and provide satellite images of the locality from the GPS coordinates obtained on the GPS test application.
- The digital multimeter to take electrical measurements (intensity, voltage, resistance, capacitance, etc.);
- Toolboxes for basic electromechanical work.

The data collection phase consisted of a physical descent on the ground which allowed the collection of data thanks to a data collection sheet. This collection, followed by a diagnosis of the electrical installations, made it possible to thoroughly examine the condition and characteristics of power sources (transformer station, generator, SBEE, etc.), electrical conduits (ducts, cables, related, electrical boxes (rescued, non-rescued, corrugated), electrical appliances (lights, switches, sockets, air conditioners, boosters, inverters, etc.).

2.3 Methods

In this section, the methods and assumptions used to carry out the technical-economic and environmental study are described. First, we will describe what a solar-conventional hybrid system is in backup mode. Then the different consumption scenarii are presented. And finally the approach used to size the PV generator is then explained. As the system operates under several uncertain economic parameters, this study includes an economic feasibility analysis using RETScreen software to study the financial viability of the different scenarios. The applied same software generated the environmental benefits of the project.

2.3.1 Hybrid system in back-up mode

The proposed hybrid back-up system is based on an uninterrupted power supply that ensures continuity of service in the event of a disruptio in the electric network. When the conventional grid is operational, the batteries are kept permanently charged by the grid and the solar field. This is not the case for conventional solar hybrid systems where only the batteries are charged by the solar array. The advantage of the hybrid back-up system is that the entire battery capacity can be used for back-up power during grid interruptions. It delivers a reliable, interference-free supply voltage within tolerances that are compatible with the requirements of sensitive electronic devices. Thus, the need for uninterruptible power supply is intended to get rid of problems caused by the instability of public electricity networks. to keep the process uninterrupted and to ensure stable, reliable operation and uninterrupted power supply to electrical equipments.

Figure 2 displays the synoptic diagram of a hybrid solar power supply in backup mode. In network mode, the load is powered from the grid and the battery is charged via the bi-directional AC/DC converter by the solar generator (whose DC energy is converted to AC by the DC/AC inverter) and also by the grid. In battery mode, the load will be fed exclusively from the battery energy via the bi-directional converter in DC/AC mode, until normal conditions are restored or the storage batteries are exhausted.

2.3.2 Evaluation of the energy balance of the building

The power balance is an essential step in the design of electrical installations. It makes it possible to realize the overall energy requirement of the installation after having noted the characteristics of the loads: voltage, power and duration of use. For photovoltaics, like any electrical installation, the power balance is the basis for the sizing of all of its components and is calculated according the equation (1) (Sanwogou *et al.* 2019).

$$B_j = \sum P_a \, \Delta t \tag{1}$$

B_j represents the energy balance in kWh/day, P_a is the power of a load in W, and Δtits duration of use in hours. To carry out the energy balance, the assumptions made are recorded in Table 1.

2.3.3 Consumption scenarios

To describe the energy consumption needs over a twenty-four (24) hour day, six (6) variants of energy consumption were considered, namely:

- Variant 1: the mini power station provides lighting and the Benin Electricity Company (SBEE) supplies the brewers, electrical outlets and air conditioners;
- Variant 2: the mini central supplies the lamps, sockets, stirrers and the SBEE operates the air conditioners;
- Variant 3: the mini power station supplies all the equipment (lamps, sockets, brewers and air conditioners) and the batteries are charged exclusively by the solar generator;
- Variant 4: The backup system supplies the lamps, sockets and stirrers in the event of an SBEE outage;
- Variant 5: The backup system supplies all the equipment (lamps, sockets, cross-connectors and air conditioners) in the event of an SBEE outage;
- Variant 6: the mini power station supplies all the equipment (lamps, sockets, brewers and air conditioners), the batteries are charged simultaneously by the solar generator and conventional energy (SBEE). This system acts as a backup in the absence of the conventional network and sunshine.

The aforementioned six variants are thoroughly analysed on the basis of numerical data in the discussion.

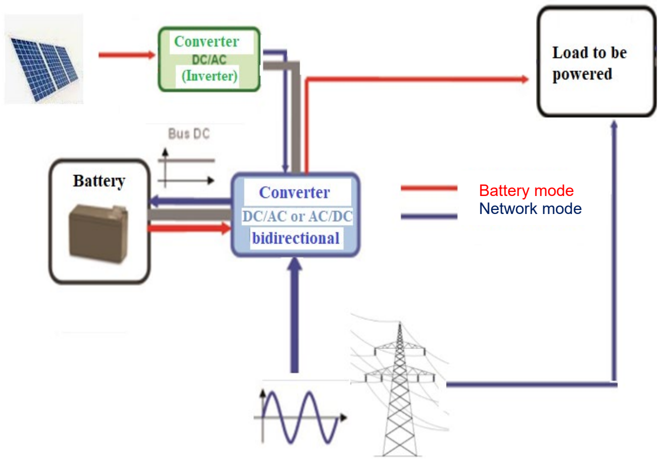

Fig. 2 Synoptic diagram of a hybrid solar power supply in backup mode

Table 1
Assumptions used for the energy balance

Devices	Operation interval	Duration/ day (h)	Simult a-neity Coef.
Interior lamps	08:00 a.m.-06:00 p. m.	10	0.9
Exterior lamps	07:00 p. m.- 06:00 a.m	12	1
Laptop	-	8	0.8
Computers	09:00 a. m.-06 p. m.	8	0.8
Brewers	09:00 a m. -06 p.m.	8	0.8
Printers	-	0.5 to 1	0.5
Air conditioners	08:00 a.m.-07:00 p. m.	11	0.7
Electric strike	-	1	1
Alarm	-	1	0.5
PA system	-	10	0.7
Fan	-	2	0.7
Camera screen	-	24	1

2.3.4 Sizing of the photovoltaic system

Of all the configurations of solar PV systems, the one retained for this study is the solar PV system AC configuration with storage (charger inverter + grid inverter). Systems based on this configuration generally perform better in cloudy or shady conditions, but incur high costs (Tekumalla et *al.* 2018). On the other hand, this configuration integrates a grid inverter and a charger inverter. The court is an administration that essentially operates between 07:00 a.m. and 07:00 p.m. The need for electrical energy is concentrated during the day. It is therefore fair to minimize storage (batteries) by applying reasonable reduction coefficients in all the scenarios to be considered. The following sub-sections successively present the calculation of the power of the photovoltaic field to be installed, the choice of the inverter, the sizing of the batteries and the determination of the section of the cables.

2.3.5 Power of the photovoltaic field

The power of the photovoltaic field (Pc) to be installed is determined by expression (2) (Al-Shamani *et al.* 2015; Amara 2015).

$$P_c = \frac{E_{cons}}{E_s \eta_{bat} \eta_{inv} \eta_{reg} K_p} \tag{2}$$

Where E_{cons} designates the electrical energy consumption per day in Wh/Day; E_s is the insolation of the site; K_p is the efficiency of the generator (losses, wiring and dirt); η_{bat} is the efficiency of the storage battery; η_{inv} is the efficiency of the inverter; η_{reg} is the efficiency of the regulator

The various returns mentioned above are evaluated at 0.65 in this study.

2.3.6 Network inverter and charger inverter

The photovoltaic energy produced by the generator is converted by an inverter which transforms the direct current into an alternating current of 230V/50Hz for example. The choice of the network inverter ($P_{net\_inverter}$) is made from expression (3) (Al-Shamani *et al.* 2015; Amara 2015):

$$0.90 \leq \frac{P_c}{P_{net\_inverter}} \leq 1.1 \tag{3}$$

The number of network inverters is given by :

$$\text{Number}_{\text{net\_inverter}} = \frac{P_c}{P_{u\_net\_inverter}} \quad (4)$$

Where $P_{u\_net\_inverter}$ is the unit power of the grid inverter

The inverter-charger sizing method is given by its power P_{ch}:

$$P_{ch} = \frac{Coef_{\_s} \sum P_{lamp} + \sum(P_{socket}\ f_c) + \sum(P_{other_{receivers}}\ f_c)}{\eta_{charg\_inverter}} \quad (5)$$

Where f_c is the expansion coefficient of the sockets, $\eta_{charg\_inverter}$ is the efficiency of the charger inverter, $Coef_{\_s}$ is the simultaneity coefficient, P_{lamp} is the power of the lamps, P_{socket} is the power of the equipment connected to the socket, $P_{other_{receivers}}$ is the power of the other loads.

The selected inverter must also meet the following conditions:

- the MPP (Maximum Power Point) voltage of the PV generator (Vmpp) must be greater than the minimum voltage allowed at the inverter input;
- the open circuit voltage of the PV generator (Voc) must be lower than the maximum voltage allowed at the input of the inverter;
- all strings (branches) connected to the same inverter must have the same DC voltage.

2.3.7 Battery sizing

Energy storage is a solution to satisfy the availability of energy for the load and to fill the fluctuating deficit of renewable energies. The storage will be used to store the surplus PV production during the day and discharge this energy if necessary during the night in order to ensure any night peaks. The minimum capacity C_B in Ah of the batteries is determined by relation (6) (Al-Shamani *et al.* 2015; Amara 2015).

$$C_B = \frac{E_{cons} n_{bj}}{D_{OD} \eta_{bat} V_{bat}} \quad (6)$$

With : E_{cons} is the daily energy requirement in Wh to be stored, N_{bj} is the number of days (autonomy) equal to 1 in the case of this study, D_{OD} (Depth Of Discharge) is the depth of discharge of the battery (70%), η_{bat} battery efficiency (80%), V_{bat} the battery voltage (V).

The batteries are arranged in such a way as to supply a suitable voltage and current to supply the load in the event of the absence of the PV generator. They are arranged either in series or in parallel depending on the desired voltage or capacitance.

- Calculation of the number of batteries in parallel: $N_P = \frac{C_B}{C_{bat}}$
- Calculation of the number of batteries in series: $N_s = \frac{U_{syst}}{V_{bat}}$
- Calculation of the total number of batteries: $N_{bat} = N_s N_p$

With C_{bat} the battery unit capacity (Ah); U_{syst} the system voltage (V).

2.3.8 Sizing of the cable section

In this subsection, we will show the determination of the section of the conductors used to connect the various components of the photovoltaic solar system between them (that is to say from the panels to the regulators; from the regulators to the battery banks of accumulators and from the latter to the converters). Resistivity flexible copper conductors $\rho = 1{,}7 \times 10^{-8} \Omega.\text{m}$ provided for wiring. The section S of the cable is calculated by the equation (7).

$$S = \frac{200\ \rho\ L\ I}{\Delta U\%\ U_{syst}} \quad (7)$$

Where ΔU% being the voltage drop in percentage; ρ, the copper resistivity in Ω.m; L, the length of a conductor in m; I, the current in amperes; U_{syst}, the system voltage.

2.3.9 Analysis of the economic feasibility and environmental impact of the solar generator

During the development of a photovoltaic solar project, the economic analysis is very important to decide on its economic and ecological viability (RETScreen International 2006; Owolabi *et al.* 2019). The hardware used for the economic analysis in this study is the RETScreen Expert-Professional-6.0.7.55 software. It is a standardized clean energy management software developed by the Government of Canada for the feasibility analysis of renewable energy projects and the analysis of energy performance.

2.4 Overview of RETScreen Expert

RETScreen International is an innovative and unique tool for raising awareness, decision support and capacity building in the field of renewable energies. It is developed and maintained by the Government of Canada, through the CANMET Energy Diversification Research Laboratory (CDRL) of Natural Resources Canada, whose center is located in Varennes, Quebec (Mehmood *et al.* 2014; Thevenard *et al.* 2000). The software is the result of the contribution of more than 307 networks of experts from industry, government and academia, with the collaboration of organizations such as the National Aeronautics & Space Administration (NASA), the Renewable Energy and Energy Efficiency Partnership (REEEP), United Nations Environment Program (UNEP), Global Environment Facility (GEF), World Bank Prototype Carbon Fund (PCF), Energy + Environment Foundation and Leonardo Energy Initiative (RETScreen 2022). Apart from the latest version of the software, known as RETScreen Expert, all other versions are readily available for free public use without any cost implications for the feasibility analysis of clean energy projects, including energy efficiency technologies and renewable energy projects such as solar photovoltaic, wind and hydroelectric projects (RETScreen 2022).

The software can be used for feasibility studies of energy projects, performance evaluation of new projects and modernization projects, as well as monitoring and evaluation of existing projects. Users can select each technology project based on the objective of their feasibility study or performance evaluation. The software helps decision makers assess the potential of certain energy projects in order to implement them quickly and inexpensively. This is done by significantly reducing the cost and time associated with identifying and evaluating potential energy projects that come through the pre-feasibility, feasibility, development, and engineering stages (Mehmood *et al.* 2014; RETScreen 2022).

2.4.1 RETScreen Expert Worksheets

- Comparative analysis

The Benchmark Calculator allows the user to quickly assess the energy performance of a facility by establishing baseline climatic conditions at the facility site for any location on the planet, and compare the energy performance of various types of reference installations with the estimated or measured annual energy consumption of the same installation (RETScreen 2022).

- Feasibility analysis

The Feasibility Analysis spreadsheet allows for a comprehensive and detailed analysis. It allows users to model any clean energy project by performing a standard five-step analysis: energy analysis, cost analysis, emissions analysis, financial analysis, and sensitivity/risk analysis (RETScreen 2022). The spreadsheet contains the baseline, product, project, hydrology and climate databases, as well as links to fully integrated global energy resource maps.

- Performance analysis

The performance analysis spreadsheet allows the user to monitor, analyze and communicate key energy performance data to operators, managers and high-level decision makers, including actual energy performance of the installation compared to the expected performance. The spreadsheet uses advanced regression and prediction models that take into account normalized energy performance based on variable parameters, such as meteorological data obtained from NASA, to track a facility's actual energy performance against its performance. predicted (RETScreen 2022).

As part of this study, the "Feasibility Analysis" worksheet was considered. The financial analysis spreadsheet of the software contains financial parameters such as inflation rate, discount rate, reinvestment rate, debt ratio, debt interest rate as variables input and automatically calculates key indicators of financial viability, such as internal rate of return, simple return, net present value, etc. (RETScreen International 2022).

The following subsection presents the correlations used in the RETScreen financial analysis model to assess the financial viability indicators of the project. The model makes the following assumptions (RETScreen International 2022):

- the initial investment year is year 0;
- costs and credits are given for year 0 and therefore the inflation rate (or indexation rate) is applied from year 1; and
- cash flows are calculated at the end of the year.

2.4.2 Mathematical model of financial viability indicators

- Internal Rate of Return (IRR) and Return on Investment (RI)

The internal rate of return IRR is calculated by finding the discount rate that brings the net present value of the project (NPV) to zero. It is calculated by solving equation (8) (RETScreen International 2022):

$$0 = \sum_{n=0}^{N} \frac{F_n}{(1+IRR)^n} \tag{8}$$

Where: N is the lifetime of the project in years, F_n the monetary rate of the year n (F_0 represents the equity invested);

- Single return

Simple return is the number of years it takes for cash flow (excluding debt payment) to equal total investment (which is equal to the sum of debt and invested equity) (RETScreen International 2022):

$$RI = \frac{C - IS}{(R_{ener} + R_{CE} + R_{GHG}) - (C_{OM} + C_{conv})} \tag{9}$$

or :
C is the total investment cost in the project; IS the sum of incentives and subsidies; R_{ener} is the annual energy saving or revenue; the income from the credit for reducing GHG emissions; R_{GHG} is the income from the credit for reducing GHG emissions; R_{CE} credit income for clean energy delivered; C_{OM} the annual cost of operation and maintenance; C_{conv} the annual cost of fuel or electricity;

- Net Present Value (NPV)

The net present value NPV of a project is the value of all future cash flows, discounted using the discount rate, in current currency. It is calculated by discounting all cash flows as expressed in equation (10):

$$NPV = \sum_{n=0}^{N} \frac{\tilde{F}_n}{(1+r)^n} \tag{10}$$

where r is the discount rate, $\tilde{F}_n$ is the after-tax cash flow of year n.

- Annual Lifetime Savings

The annual life cycle savings (E_{LCA}) is the equivalent value of constant annual savings which, over the duration of the project, would give the same net present value (RETScreen International 2022). The annual life cycle savings are calculated from equation (11):

$$E_{LCA} = \frac{NPV}{\frac{1}{r}\left(1 - \frac{1}{(1+r)^N}\right)} \tag{11}$$

- Cost price of energy

The cost price of energy is the avoided energy cost which gives a net present value equal to zero (RETScreen International 2022). The cost price of energy R_{prod} is therefore obtained by solving equation (12).

$$0 = \sum_{n=0}^{N} \frac{\tilde{F}_n}{(1+r)^n} \tag{12}$$

or

$$\tilde{F}_n = F_n - I_n \tag{13}$$

$$F_n = F_{in.n} - F_{out.n} \tag{14}$$

$$F_{in.n} = R_{prod}(1+r_e)^n + R_{pow}(1+r_i)^n + R_{CE}(1+i_{CE})^n + R_{GHG}(1+i_{GHG})^n \tag{15}$$

F_n is the cash flow of year n; I_n is the annual tax equal to the tax rate specified by the user, multiplied by the net income of this year; $F_{in,n}$ is the inflow before tax in year n; $F_{out,n}$ is the pre-tax outflow in year n ; r_e the energy indexation rate; r_i is the inflation rate; i_{CE} the indexation rate of the clean energy credit; i_{GHG} the indexation rate of the credit for greenhouse gas (GHG) reduction; R_{pow} is the saving or the annual income of the guaranteed power.

- Cost of reducing GHG emissions

The cost of reducing GHG emissions, CRE, represents the annualized cost that must be incurred to avoid each tonne of GHGs. It is calculated using equation (16).

$$CRE = \frac{E_{LCA}}{\Delta_{GHG}} \tag{16}$$

where E_{LCA} are the annual life cycle savings calculated with equation (10) and Δ_{GHG}, the annual reduction in GHG emissions, calculated in the Greenhouse Gas (GHG) Emission Reductions Analysis worksheet by equation (17).

$$\Delta_{GHG} = (e_{ref} - e_{prop})E_{prop} \times (1 - \lambda_{prop})(1 - e_{cr}) \quad (17)$$

where e_{ref} is the GHG emissions factor for the reference case, e_{prop} the GHG emissions factor for the proposed case, E_{prop} the annual quantity of electricity produced by the proposed case, λ_{prop} the fraction of electricity lost in transmission and distribution in the proposed case and, e_{cr} transaction fees for GHG credits.

3. Results

In this section, the results of the technical and financial analysis are presented.

3.1 Kandi climate data

Climate data for Kandi locality was estimated by RETScreen using National Aeronautics and Space Administration (NASA) data as shown in Table 2. The used data covers the period from 1983 to 2022 (RETScreen International 2022). During this period, the monthly average irradiation have been computed. In Figure 3 is presented this monthly variation.

Irradiation in the commune of Kandi presents a bimodal regime. We noted a first peak around the months of March-April and a second less pronounced peak during the months of October-November. The monthly average irradiation varies between 4.89 kWh/m²/day and 6.30 kWh/m²/day respectively obtained in August and April as shown in Figure 3. For the sizing of the components of the photovoltaic plant, the irradiation of the most unfavorable month (4.89 kW/m² in August) is taken into account in the simulations.

3.2 Energy balance of the Kandi Court

Table 3 presents the energy balance of the building of the Tribunal of Kandi. Table 3 indicates a daily consumption of 393173 Wh/day. The components of the solar field can thus be sized from the daily consumption obtained.

The energy produced by any solar module depends on the solar radiation of the location and the number of sunny days (Mehmood *et al.* 2014; Khandelwal and Shrivastava 2018). The energy produced by the solar generator affects both the annual energy exported and the utilization factor. The utilization factor is the ratio between the energy produced by the photovoltaic plant during the year and the energy produced at its nominal capacity during the year (Khandelwal and Shrivastava 2018). To meet the energy needs of the Kandi court, the six (6) scenarios previously described are analysed. The following subsection presents the load profile of the different scenarios.

Table 2
Kandi climate data

Settings	Value
Latitude	11.1
Longitude	2.9
Elevation	292
Average annual design heating temperature (°C)	16.9
Average annual air conditioning design temperature (°C)	38.8
Average annual air temperature (°C)	27.8
Average annual irradiation (kWh/m²/day)	5.68

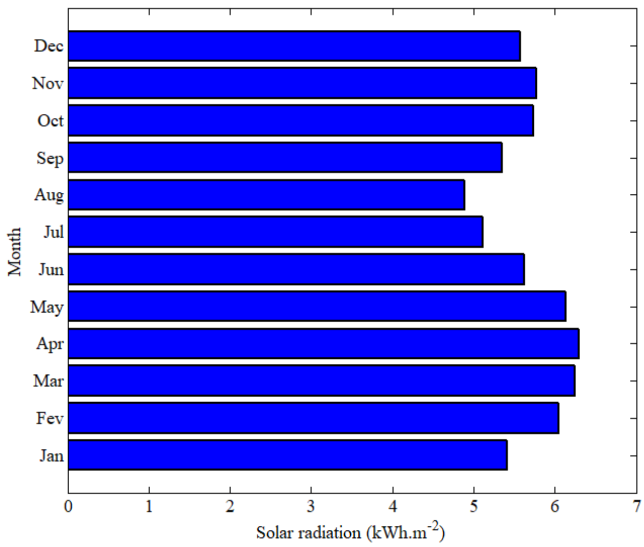

Fig. 3 Histogram of variations in monthly average irradiation in the study area

Table 3
Kandi court energy balance

Devices	Total power (W)	Simultaneity coefficient	Starting coefficient	Energy (Wh/day)
Interior lamps	1590	0.9	1	15660
Exterior lamps	220	1	1	2640
Laptop	1000	0.8	1	6400
Computers	8400	0.8	2	64,960
Brewers	2305	0.7	2	9387
Copier	3000	0.5	3	1500
Printers	4620	0.5	1	2310
air conditioners	32016	0.7	3	245,750
Electric strike	1200	0.5	1	600
Alarm	900	0.5	1	450
PA system	2400	0.7	2	16,800
Fan	140	0.7	2	196
Camera screen	1105	1	1	26,520
		Total		**393,173**

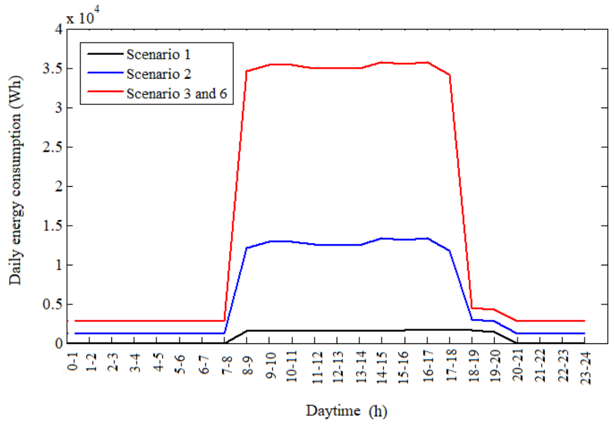

Fig. 4 Load profile of the different scenarios.

3.3 Load profile of the different scenarios

The load profiles of the base scenarios (1, 2, 3 and 6) are presented in Figure 4. For scenario 1, the peak power is 1671W with a daily consumption of 18,300 Wh. The peak power is 31,645 W with a daily consumption of 147,423 Wh for the scenario 2. The solution proposed for this scenario is a mini solar power plant supplying the lamps, the sockets and the cross-connectors, while the air conditioners being supplied by the conventional network. For scenarios 3 and 6, the loads reached a peak power of 98872.6 W with a daily consumption of 393,173.4 Wh. For scenario 6, the fraction of solar energy in the back up system is around 37%.

The solution proposed for scenario 4 is a backup system supplying the lamps, sockets and stirrers with an autonomy of 4 hours while the Beninese Electricity and Water Company (SBEE) supplies the air conditioners and that of scenario 5 takes into account all the equipment (lamps, outlets, brewers and air conditioners) for 4 hours of autonomy. The daily energy consumption of scenarios 4 and 5 are evaluated respectively at 74, 11 kWh, 163,754.8 kWh for a peak power of 31,639 W and 98,872.6 W respectively. Knowing the daily consumption, the different components of the photovoltaic system can be sized. It can therefore be noted that in all scenarios the maximum consumption occurred in the daytime as the bulding is a public administration which only operates during the day.

3.4 Solar field sizing results for each scenario

Table 4 shows the size and number of components chosen for the scenarios. From these results, it is observed that the solar generator in the case of scenario 3 has the largest peak power (134 kWp) and the largest battery capacity (14687 Ah). This is explained by the fact that this scenario takes into account all of the court's charges to be served. Scenario 5 does not include a photovoltaic field, the batteries supply part of the load. These batteries are recharged by the conventional network (SBEE). It should also be noted that scenarios 3 and 6 are similar except that the peak power of the solar generator of scenario 6 (49.5 kWp) is lower than that of scenario 3. This difference is justified by the fact that the park number of batteries in scenario 6 is recharged simultaneously by the solar field and the SBEE source, unlike scenario 3 where the park is recharged exclusively by the solar field. However, when the conventional source (SBEE) is withdrawn, the solar installation in the case of scenario 6 can ensure energy autonomy of 10hr 40 in court. The usage voltage of the solar installation is set at 48V for all scenarios.

The characteristics of the components chosen for the different types of solar installations are shown in Table 5. The section and length of the cables to be used are as follows:

- Between the PV array and the input box, the cable section is 35 mm² for a length of 20 m;
- Between the controller, the box and the PV inverter, the cables have a section of 35 mm² with a length of 20 m;
- Between the charger inverter and the battery bank, the section of the cable is 50 mm² and the length is 20 m.

3.5 Financial viability

In the development of a photovoltaic solar project, the study of the financial viability is very important to know if the project is economically viable and sustainable (Owolabi *et al.* 2019). The financial analysis spreadsheet of the software contains some financial parameters including inflation rate, discount rate, reinvestment rate, debt ratio and debt interest rate as input variables, as mentioned in Table 6. The input variables are standards obtained directly from the software according to the location, with the exception of the investment cost and the operating and maintenance cost which were entered by the user. According to (Mehmood *et al.* 2014), the financial viability of a project is a measure of its NPV, its IRR and its payback period. For the different scenarios, the NPV, which is the difference between the present value of cash inflows and the present value of cash outflows over a given period, was calculated.

Table 6
RETScreen Input Financial Parameters

Financial parameters	Values
Inflation rate %	4.3
Discount rate %	4.25
Project lifetime years	20
Debt ratio %	0.1
Interest rate on debt %	4
Price of exported electricity (USD)	0.26
Cost of operation and maintenance (USD)	709

Table 4
Size of production system components

Devices	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Daily needs (kWh/day)	18.3	147,423	393,173	74.11	163,754	393,173
Peak power (kWp)	6.23	50.24	134	25.25	-	49.5
Number of panels	15	112	300	28	-	112
Capacity (Ah)	681	5484	14,627	2757	6,092	6,340
Number of batteries	24	48	120	24	48	48
Number of inverters	1	2	6	2	-	2
Number of charger inverters	1	6	18	6	18	18

Table 5
Types of scenario system components

Devices	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
PV modules	450 Wp / 24V	450 Wp / 24V	450 Wp / 24V	450 Wp / 24V	450 Wp / 24V	450 Wp / 24V
Batteries	OPZv 750Ah/2V	OPZv 3170 Ah/2V	OPZv 3170 Ah/2V	OPZv 3170 Ah/2V	OPZv 3170 Ah/2V	OPZv 3170 Ah/2V
Grid inverters	-	STP 25000TL	STP 25000TL	STP 15000TL	STP 25000TL	STP 25000TL
charger inverters	5kW/48V-MPPT 80A	8kW SMA SI 8.0H	8kW SMA SI 8.0H	6kW/48V-MPPT 80A	8kW SMA SI 8.0H	8kW SMA SI 8.0H

In the context of this study, the initial investment comes from equity. The debt ratio chosen is therefore negligible as shown in Table 6. Based on the input variables, the rate of return (IRR), the net present value (NPV), the annual savings (Ecan), the cost price of electricity (P/kWh), the simple return (RI) and the investment cost were calculated and presented in Table 7.

The results of the financial analysis show that the NPV for scenarios 2, 3 and 6 are positive. The project is therefore economically feasible for these three scenarios unlike the other scenarios (1, 4 and 5) whose NPV is negative. The value of the IRR, which is a measure of the profitability of a project, obtained for scenarios 2, 3 and 6 is higher than the discount rate (Bermeo *et al.* 2021). This therefore makes the project profitable for scenarios 2, 3 and 6. Considering the payback period, the project in Scenario 5 has the longest payback period (greater than the duration of the project) while the project in Scenario 6 has the shortest payback time, i.e. 5,1 years. The cost price of energy in the case of scenario 6 (0.14 USD/kWh) is lower than in scenarios 2 and 3 (0.17 USD/kWh; 0.15 USD/kWh). The project in scenario 3 generates annual savings of USD 35,542 compared to USD 33,674 and USD 11,819 for scenarios 6 and 2 respectively. Considering these various financial parameters such as the payback time , the annual savings (Ecan), the cost price of electricity (Price/kWh), and given the high amount required by scenario 3, the scenario 6 is the more profitable and economically feasible for the court in Kandi.

3.6 Environmental analysis

The emissions analysis sheet is used to calculate the reduction in greenhouse gas (GHG) emissions resulting from the construction of the photovoltaic solar installation. It is also used to calculate the revenue that can come from the sale of GHG emission reductions. Transmission and distribution losses of 7% for Benin's power grid and GHG emission factor of 0.772 tCO_2/MWh were considered. The software calculates the gross annual reduction in GHG emissions by subtracting the emission calculated in the proposed case (scenario) from the emission obtained for the base case. The results are listed in Table 8.

Table 7
Financial viability

Financial viability	IRR (%)	NPV (USD)	Ecan (USD) year)	Simple return (years)	Price (USD) /kWh)	Amount (USD)
Scenario 1	-1.3	-19 305	-1 452	25.2	0.47	45, 060
Scenario 2	8.6	156, 447	11, 819	8	0.17	161, 515
Scenario 3	14.5	470, 442	35, 542	7.3	0.15	401, ,636
Scenario 4	-7.3	-62,421	-4 716	52	1.40	85, 501
Scenario 5	-17.9	-153,899	-11, 627	213	2.15	162 ,951
Scenario 6	21.2	445, 720	33, 674	5.1	0.14	212 ,920

Table 8
Gross annual reduction in $C0_2$ emissions

	Reference case (tCO_2)	Proposed case (tCO_2)	Gross GHG reduction (tCO_2)
Scenario 1	7.4	0,5	6.8
Scenario 2	61.5	4.3	57.2
Scenario 3	164	11.5	152.5
Scenario 4	13.7	1	12.7
Scenario 5	4.4	0.3	4.1
Scenario 6	124.5	8.7	115.8

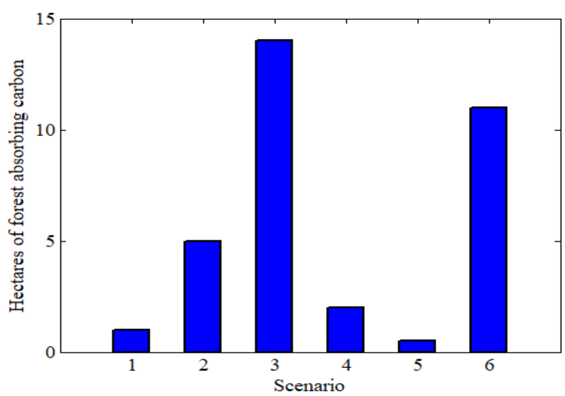

Fig. 5 Equivalence of gross annual reduction in CO_2 emissions

Figure 5 presents the reduction equivalence in terms of the number of hectares absorbing carbon. The Scenario 3 project has a maximum annual GHG emission reduction of 152.5 t CO_2 , which equates to 14.0 hectares of carbon-absorbing forest that were not cut during the lifetime of the project. It is followed by the Scenario 6 project with a reduction in CO_2 emissions of 115.8 t CO_2 , or 10.6 hectares of carbon-absorbing forest preserved.

Scenario 6, in addition to being economically viable, favors a great reduction in GHG emissions. This scenario is suitable for jurisdictions in Benin because of its technical, economic and environmental benefits.

4. Discussion

Depending on the specifics of the facilities and sites to accommodate these works, the size of the solar generator, the cost price of the solar energy produced, the economic parameters such as the internal rate of return, the net present value, the return on invested capital (DRI), the profitability index, the annual savings achieved have been evaluated in the literature (Table 9).

In this study, the best solar configuration deduced from the simulations (scenario 6) led to a cost price per kWh of electricity estimated at 0.14 USD, equivalent to an annual saving of 33, 674 USD (a significant amount in the financial budget of such an institution in Benin), a payback time of 5.1 years and an internal rate of return (IRR) of 21.2%. By comparing these results with those of (Benelkadi *et al.* 2018) in Algeria, (Salisu *et al.* 2019) in Nigeria, (Aboagye *et al.* 2020) in Ghana, (Sanwogou *et al.* 2019) in Togo, (Imam *et al.* 2019) in Saudi Arabia, (Dagtekin *et al.* 2014) in Turkey, (Vakili *et al.* 2022) in Italie, (Poudyal *et al.* 2021) in Nepal, we deduce that the price per kWh of electricity obtained for scenario 6 is higher. However, the price displayed in the work of (Hanen *et al.* 2018) in Tunisia, (Singh and Rizwan 2023) in India, (Hassanea *et al.* 2022) in Tchad is respectively much higher (0.81 USD/kWh, 0.61USD/kWh, 0.33 USD/kWh) than ours as well as the return on investment period obtained by (Aboagye *et al.* 2020) in Ghana (15 years), (Sanwogou *et al.* 2019) in Togo (8.6 years), (Dagtekin *et al.* 2014) in Turkey (7.8 years), (Imam *et al.* 2019) in Saudi Arabia (14.6 years), (Vakili *et al.* 2022) in Italie (6.2 years), (Poudyal *et al.* 2021) in Nepal (8.6 years). The studies of Amoussou in Benin and more precisely in the city of Kandi confirms the results of this study on the price of kWh which varies from 0.09 USD to 0.23 USD for a system without storage and with energy storage according to the 'author. But the return-on-investment time obtained by the latter, whether with or without storing the energy produced (8 to 11 years), is greater than that of scenario 6 of our study. The long-term saving achieved by the solar system studied by (Sanwogou *et al.* 2019) in Togo, (Doudou 2016) in Niger and (Windarta *et al.* 2020) in Indonesia indicates values that are much lower than those generated by scenario 6. As for the studies of Bourahla *et al.* 2019) in Algeria, (Bermeo *et al.* 2021) in Ecuador, (Hanen *et al.* 2018) in Tunisia, (Doudou 2016) in Niger, (Yaniktepe *et al.* 2017) and (Windarta *et al.* 2020) in Indonesia, the authors observed dates that vary between 6 years and 21 years as the return on their investment.

Table 9
Technical and economic parameters of some works encountered in the literature

Authors	Country City	Power installed (kWp)	Cost of electricity USD/ kWh	IRR (%)	NPV (USD)	Annual savings (USD)	Greenhouse gases saved ton/year	RI (years)
Benelkadi *et al.* 2018	Algeria	-	0.05	-	-	-	-	-
Bourahla *et al.* 2019	Algeria (Oran)	452	-	5	15, 798	-	-	10.3
Sanwogou *et al.* 2019	Togo (Kara)	15.84	0.07	12.2	587.17	7, 599.9	7	8.6
Hanen *et al.* 2018	Tunisia (Tozeur	10,000	0.81	-	-	-	-	21
Doudou 2016	Niger (Gadafawa)	56	-	-	-	12, 963.53	57.8	8
Aboagye *et al.* 2020	Ghana (Kumasi)	6	0.10	-	-	-	-	15
Salisu *et al.* 2019	Nigeria	160	0.09	-	921, 741	-	2.88	-
Amoussou 2018	Benin (Kandi)	12000	0.09 à 0.23	-	369, 287	-	-	8 to 11
Yaniktepe *et al.* 2017	Turkey (Osmaniye)	1000	-	10.36	99, 212	-	-	8.3
Dagtekin *et al.* 2014	Turkey (Adana)	100	0.008	-	27, 039	-	0.20	7.8
Bermeo *et al.* 2021	Ecuador (azogues)	62.4	-	7.33	378.38	-	-	6
Imam *et al.* 2019	Saudi Arabia	12.25	0.034	-	3, 880.17	-	-	14.6
Windarta *et al.* 2020	Indonesia (Semarang)	4.8	-	13	1, 628.16	109.80	-	10
Kristiawan *et al.* 2022	Indonesia (University)	150	-	4.9	283 257	-	-	14.29
Vakili *et* al. 2022	Italie	-	0.053	11	-	-	-	6.2
Poudyal et al. 2021	Nepal, (Kathmandu)	3	0.06	-	-	-	10.33	8.6
Singh and Rizwan 2023	India (Uttar Pradesh)	6.5	0.61	-	-	-	-	-
Hassanea *et al.* 2022	Tchad	134-2041	0.32-0.33	-	-	-	-	-
Present study	Kandi Court (Benign)	49.5	0.14	21.2	445, 720	33, 674	115.8	5.1

These estimates are higher than those shown in this study. Similarly, the internal rate of return (IRR) of 5% indicated in the studies of (Bourahla *et al.* 2019), of 10.36% by (Yaniktepe *et al.* 2017), 7.33% by (Bermeo *et al.* 2021), 12.2% by (Sanwogou *et al.* 2019), 13% by (Windarta *et al.* 2020) and 11% by (Vakili *et al.* 2022) are well below the rate of return evaluated at 21.2% observed by the present study. It should be noted that almost all of the above projects showed a positive NPV; which indicates a good profitability of solar energy systems even if in the work of (Kristiawan *et al.* 2018) the solar feasibility project carried out by the authors seemed unfeasible. In addition, by analyzing the prices of kWh for a renovation project to be profitable in Cuba displayed in the studies of (Iakovleva *et al.* 2022), we note that this cost is quite low (at least 0.034 USD) and shows an increasingly remarkable accessibility of solar technology to populations and the importance of its use as a reliable source of energy to ensure energy autonomy.

In short, the economic parameters such as the net present value and more specifically the time to return on investment and the economic rate of return generated by scenario 6 are better than those encountered in the literature. These results lead to a better economic viability of the configuration of scenario 6 according to the criteria defined in (Mehmood *et al.* 2014). This configuration, which takes into account a mixed production of energy, therefore has many advantages. It is strongly recommended, especially for administrative and other sites whose consumption is maximized during the day. This option could therefore facilitate a faster and more sustainable integration of solar energy into energy production systems.

5. Conclusion

In this study, an in-depth feasibility analysis was carried out to assess the viability of installing a back-up system in Beninese jurisdictions by analyzing the technical, financial and environmental impact of the project. Solar installation will serve to reduce Kandi Court's electricity bill costs and greenhouse gas emissions. NASA climate data for Kandi and financial parameters such as reinvestment rate, inflation rate and discount rate were used for financial analysis as input variables in RETScreen Expert software. The sizes of the components of the photovoltaic system were calculated from the analytical formulas. The software accurately calculated financial viability indicators such as net present value, payback time, internal rate of return and annual savings not to mention the amount of greenhouse gases reduced by the project.

Among the six scenarios studied, the scenario that supplies the entire load (scenario 3), the one that takes into account the lamps, sockets and stirrers (scenario 2) and the case where the batteries are charged simultaneously by the solar generator and the conventional network (scenario 6) are profitable. Scenario 6 which has a peak power of 49.5 kWp (112 modules of 450Wp), a battery capacity evaluated at 14627 Ah (48 batteries of 3170 Ah/2V), with two grid inverters of 25 kW and 18 inverter chargers of 8 kW was considered the best option. This choice is justified by the shortest return on investment time (5.1 years), the lowest energy cost price (0.14 USD) and the annual savings generated (33,674 USD) given the investment. initial need compared to scenario 3. Additionally, this scenario give e large GHG emission reduction of 115.8 tCO_2, or 10.6 hectares of carbon-absorbing forest preserved over the lifetime of the project.

The performance observed with scenario 6 is suitable for the Kandi court because of its economic and environmental advantages. This configuration is therefore strongly recommended for the jurisdictions of Benin and also on administrative or similar sites close to the conventional network in order to henceforth optimize the contributions of solar energy in the energy mix which will be the subject of our next work. The whole system could also be improved with the adjuction of other renewable energy sources as small scale wind turbines, the use of solar absorption air conditioners to form a solar polygeneration system (Missoum and Loukarfi., 2021).

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