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# The economic feasibility analysis of generated photovoltaic energy in the USTO campus

***Abstract.*** *The aim of this study is to analyze the economic impact of photovoltaic energy generation by a prospective campus microgrid to be installed at the University of Science and Technology (USTO). In this work, hourly solar irradiation and temperature data provided from the local weather office is used to study the distribution and duration of solar radiation over the campus. The generated solar photovoltaic energy is analyzed taking into account the economic aspects such as the photovoltaic system capital investment cost and the annual power generation cash flow. The installed power of the photovoltaic plant was calculated and the generated energy estimed. The feasility analysis shows a payback year of of 10,3, an internal rate of return of 5% and a profitability index of 1.*

***Streszczenie.*** *Przedstawiono analizę fotowoltaicznego układu zasilania zastosowane go w kampusie uniwersytetu USTO w Oranie. Amalizowano głównie koszty, opłacalność ekonomiczną i zwrot kosztów inwestycji.* ***Analiza aspektów ekonimicznych sieci fotowoltaicznej na przykładzie kampusu uniwersytetu USTO w Oranie***

**Keywords:** Grid-connected photovoltaic system- PV array - Microgrid – Renewable energy - Economic analysis.
**Słowa kluczowe**: sieć fotowoltaiczna, aspekty ekonomiczne

## Introduction

The development and use of clean renewable energy in many parts of the world in the last two decades have become vital due to the continuous decline and price fluctuation of fossil fuel resources and global concerns about climate change, air pollution and increased consumption of energy [1,2].

Advances in power electronics have also contributed more effectively and more reliably to the integration of renewable resources into power grids [3]. The cost reduction of photovoltaic (PV) technology and related components, such as inverters and batteries, and the sharp decline in the cost of large wind turbines have made these energy sources more attractive in many countries.

The large-scale development of renewable energy systems and their integration to utility grid are considered as the most important challenges for the sustainable environment. The electric energy industry restructuring and the introduction of the concept of a smart grid have also led to new technologies (distributed energy resources and decentralized generation) become more and more widely adopted [3]. Since the industrial and residential sectors are among the largest consumers of electrical energy, decentralized electricity generation has now become a potential solution for satisfying the energy needs locally. In comparison to large-scale wind energy, the cost of deploying a PV system is much higher, and therefore implying that a larger financial subsidy is needed to increase the PV installation capacity by customers [4,5,6]. Microgrids are small size electrical networks built to provide a reliable electric supply and with a better quality for a small number of consumers. They consists of local power stations (micro turbines, fuel cell, small diesel generators, photovoltaic panels, etc), loads, storage batteries and a power management strategy for the supervision and dispatching power flow. They can operate either in grid-connected mode or in isolated mode. The concept can be applied to buildings, industrial areas and businesses, neighborhood of houses, etc. [7,8].

In recent years, PV systems are more and more in demand because of the continuing decline in the cost of the PV system components. New markets have emerged outside Europe and the United States (USA) through specific national and transnational incentive programs. These programs have led to a significant increase of PV electricity production over the past 30 years [1,9]. In addition, the advantage of PV as a renewable energy source is that no supplementary energy resources are required, there are no moving parts in the system and the maintenance costs are relatively low. Furthermore, as the rate of use of photovoltaic energy increases, the cost of producing photovoltaic electricity decreases [10]. In addition, the environmental impact is not the only driver for renewable energy deployment in the world, but cost-effective electricity generation also plays a key role. This efficient solar generation can be achieved by considering certain factors that are directly or indirectly associated with the end-user energy costs generated by PV systems. These include the economic state of the region and the country, electricity prices, tax rates, energy policies and programs (incentives, plans and other investment options), the efficiency of the PV system, technology, market and solar radiation [9]. Several studies have shown that PV systems will be widely used in the future, given the rapidly declining cost of photovoltaic systems [11].

Because of its large reserve and its dependence of hydrocarbons, Algeria, only recently, has started the development of renewable energies resources. Up till now, its economy remains mainly based on oil and gas which account for 98% of the country's exports. Algeria has a huge potential of renewable energy resources, and the country is committed to exploit it. To date, Algeria has 22 PV plants, with a total capacity of 350 MW. By 2030, Algeria aims is to achieve a 27% share of green energy in its national electricity mix (against only 2% at present) [12].

With an average of 3 500 hours of sunshine per year, Algeria is expected to become a potential producer of solar energy. According to energy experts, the Algerian Sahara would offer the best investment / profitability ratio in the world [12].

A new 4,025 MW solar energy project is to be launched as part of the national renewable energy development policy adopted in 2011 and updated in 2015. This solar power farm will consist of three lots of 1,350 MW each. The project also envisages to build an industrial plant for the manufacturing photovoltaic system components. Six solar power plants are to be built in six different regions of the South and Highlands, which have already been determined.

They will be in the cities of Bechar, Ouargla, El Oued, Djelfa, M'sila and Biskra.

For Algeria, renewable energy is not only useful for its future energy needs, but also represents a potential economic investment for the export of electricity to Europe. According to Algerian government reports, national gas production will quickly become insufficient to meet the needs of the country. According to the government figures released in January 2018, the development of renewable energies would save Algeria nearly 300 billion cubic meters of natural gas [13].

An economic analysis must be carried out to evaluate the profitability to ensure that the investment cost can be recovered throughout the life cycle. More studies on the profitability analysis have been carried out. The main factors affecting PV deployment are the initial capital cost of the system, the feed-in tariff and the capital cost subsidy rate [14].

Over the last years, several studies have been carried out worldwide to analyse the economic benefits of the production of electricity from solar energy. Examples of these studies were carried out on 1 MWp photovoltaic power plant in Farafenni (Gambia) [15]. In Oman, they used a 5 MW solar photovoltaic plant for 25 sites. Other economic analysis were undertaken on a PV plant connected to the 1,2 MW network installed at Colorado State University-Pueblo,PV system having an installed capacity of 5 MWp in Jordan, and on a photovoltaic plant of 1 MWp in Osmaniye [1].

The objective of this paper is to investigate the economic feasibility of the implementation of solar photovoltaic energy in Oran, the second largest city located in the West of Algeria and examine the economic benefits of solar energy and finally draw the main conclusions and recommendations.

The paper is organised as follows: The section 2 is dealing with sizing of the University Campus PV system and estimation of solar energy potentials. The section 3 presents detailed economic analysis using mathematical equations to calculate the return on the investment, the internal rate of return, the net present value (NPV), the payback years and the profitability index. The results and discussions are presented in the last section.

**Photovoltaic system dimensioning and campus solar potential estimation**

The Algerian government has adopted a series of support measures for the promotion of renewable energies through the establishment of a favorable legal framework and a National Fund for Energy Management and Renewable Energies and Cogeneration (FNMEERC) which is supplied annually with 1% of the oil royalty and the product of certain taxes [16]. Highest potential of solar resources in the world are situated in Algeria because of its geographical location. The average annual solar radiation and the sunshine duration across the whole country, are estimated at 5,7 kWh/m$^2$/day and 2 000 hours per year respectively. This latter can reach 3 900 hours in the highlands and Sahara regions. The energy received daily on a horizontal surface of 1 m$^2$ is around 5 kWh across the whole country. The highest regions are the Sahara, the highlands and the coastal region to the North with 2 263 kwh/m$^2$/year and 1 700 kWh/m$^2$/year respectively. This latter is less important than the southern regions but remains sufficient to provide solar energy. This solar energy exceeds 5 billion GWh [17].

The support proposed by the government for the promotion of solar energy is done through the mechanism of feed-in tariff guaranteed (Table 1). This system allows solar energy producers to profit from tariffs granting them a reasonable return on their investment over a 20 year eligibility period. During this period, the producer receives, in the first five years period, a fixed single purchase tariff which is calculated based on an estimated reference potential of 1 500 hours of full operation charge. In the second phase, and for the remaining duration of the contract, this single tariff can be readjusted, according to the real potential of the site [18]. Beyond this period, facilities can still operate without benefiting from this mechanism. However, the solar energy produced payback will be evaluated at the market rate. The additional costs generated by these rates will be borne by the FNER as diversification costs, the distributor who buys this energy at the guaranteed purchase rate is therefore reimbursed for the difference between the guaranteed purchase price and a tariff of reference which is the average price of conventional electricity [16].

The characteristics of solar radiation variation for a position are determined by measuring solar radiation in that position. Maximum and minimum total solar radiation observed in 2015 are shown in Fig. 1. In addition, the highest monthly average radiation of 5,0 kWh/m$^2$/day was recorded in May 2015, while the lowest monthly average solar radiation was 2,45 kWh/m$^2$/day in December 2015.

As can be seen in Fig. 1, the monthly mean values of global solar radiation remain almost constant every month and each year. As a result, the total value of solar radiation measured based on 2015 was about 1,65 MWh/m$^2$/year for a full year. The average daily solar radiation measured hourly during 2015 is also shown in Fig. 2, as can be seen from this figure, the highest and lowest values of the average monthly total solar total radiation are 1100W/m$^2$ and 650W/m$^2$ in 2015 [19].

Table 1. Guaranteed feed-in tariff per power range and according to the potential in euro / kWh

| Regulatory adjustment limit | Number of hours of operation (kWh / kW / year) | Guaranteed feed-in tariff (euro/kWh) | |
|---|---|---|---|
| | | Phase I | Phase II |
| -15% | 1275-1349 | 0.116 | 0,146 |
| | 1350-1424 | | 0,137 |
| | 1425-1499 | | 0,127 |
| Reference potential | 1500-1574 | | 0,116 |
| +15% | 1575-1679 | | 0,105 |
| | 1650-1724 | | 0,095 |
| | ≥1725 | | 0,086 |

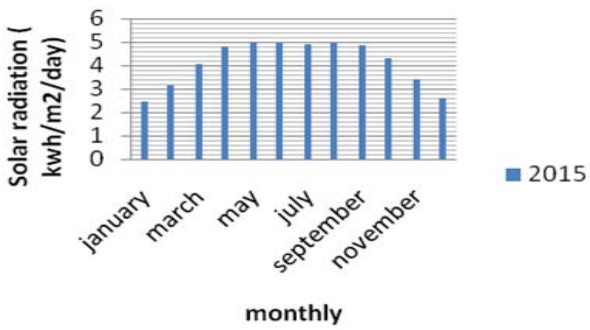


Fig.1. Monthly average of daily solar radiation throughout 2015.

Table 2 shows the monthly measured average radiation and the average temperature. Moreover, Oran has a significant solar energy potential to produce electricity. To provide the specific power at a specified voltage and current, PV modules can be collocated to form a PV array. For this purpose, 245 W peak PV modules which contain monocrystalline silicon solar cells are used [20]. The data acquisition system and software tools used in this study can import weather data from a dozen different sources as well as personal data. It will allow us to size the photovoltaic installation on campus. In this way, it can be deduced that the total installed capacity of the solar power plant consisting of 1 845 modules and calculated using the technical specifications of Table 3 is 452 kW. The PV system will be installed on the campus buildings roofs.

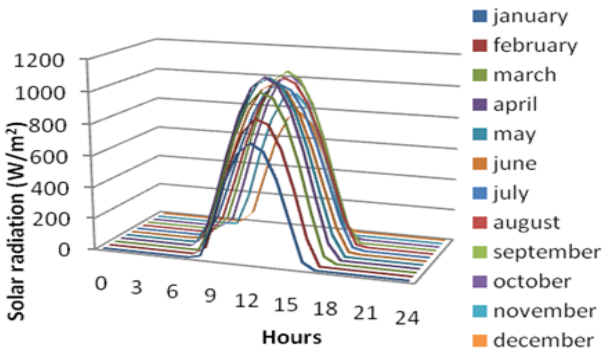


Fig.2. Hourly measured monthly average daily global radiation for 2015

These roofs have flat surfaces and the required inclination of each photovoltaic panels is 36°. The total covered surface is approximately 3 000 $m^2$ for a total of 20 roofs. To determine the total generation electricity from the PV system accurately, the PV module, inverter and external transformer losses are taken into consideration. The calculated energy injected into the local grid is 604 102 kWh/year in Oran. A basic evening power consumption of about 150 kW corresponding to lights and devices in standby can be noticed [19,22]. The power consumption for a winter day can reach almost 1 000 kW unlike a summer day where it reaches to 550 kW. As shown in Fig. 3, the daily consumed power over the year presents important peaks in the winter from January to March but also in the summer during the month of June. A drastic decrease of consumption can be observed during the weekend and represents the lowest energy consumption. According to Fig. 3, the maximum power peaks that can be reached is 1 050 kW in winter period and 700 kW in summer period. The minimum power is 150 kW during weekends.

Table 2. Daily average measurement data

| Months | Daily average radiation ($kWh/m^2$) | Daily average temperature (C°) [21] |
|---|---|---|
| January | 2,45311488 | 10,3 |
| February | 3,14340703 | 11,4 |
| March | 4,06018611 | 13,7 |
| April | 4,79475285 | 18 |
| May | 5,00881897 | 20,7 |
| June | 4,93664186 | 22,5 |
| July | 4,8976206 | 27,3 |
| August | 4,95154414 | 27,6 |
| September | 4,84672324 | 23,7 |
| October | 4,32233579 | 21 |
| November | 3,39003843 | 15,4 |
| December | 2,58747094 | 12,8 |

The campus electrical network combined with the PV system is shown in Fig. 4. This network is supplied with 10 kV from the national grid. Electrical energy is supervised by an energy center inside the campus. This electrical energy feeds the entire campus consisting of 9 zones and each zone contains different loads. Each zone is equipped with a MV/LV transformer and several protection circuits (circuit breakers, fuses, etc.). The PV generator, which consists of photovoltaic panels, will be connected to each zone via a power conversion stage (DC/DC and DC/AC). This proposed microgrid configuration contributes in the reduction of electricity bill and ensures autonomy of supply in certain situations. The PV generator consists of a total of 1 845 solar panels. Based on the calculations, the electrical energy generated by the PV panels will be sufficient to satisfy the electricity needs of all the campus facilities and will reduce the energy demand from the grid.

Table 3. Technical specifications of the photovoltaic module used [23]

| Module specifications for standard conditions of 1000W/$m^2$ ,25°C and AM=1.5 | |
|---|---|
| Rated power (Pmax) | 245 W |
| Current at Pmax | 8.2 A |
| Voltage at Pmax | 30.1 V |
| Short-circuit current | 8.7 A |
| Open-circuit current | 37.7 V |
| Coefficient of current (Ki) | 0.032 A/C° |
| Coefficient of voltage (Kv) | -0.32 V/C° |
| Number of cells in series (ns) | 60 |

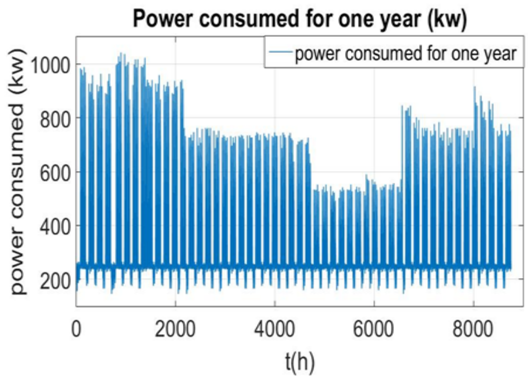


Fig.3. Power consumption data for one year

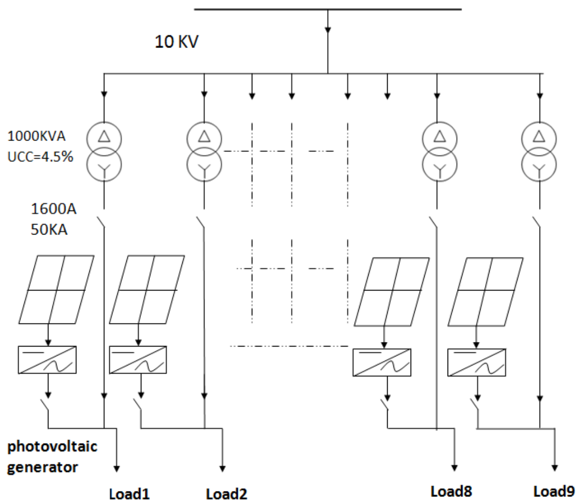


Fig. 4. Electrical diagram of the campus microgrid.

A series of simulation results are presented to illustrate this situation. During weekends, the electrical power generated from PVs will be sufficient to satisfy the consumption as shown in Fig. 5 and 6. Fig 7 and 8 show the electrical energy supplied by the PVs during the other days of the week, energy will not be enough but the demand from the electric provider will be less than without the contribution of the PV especially in summer where the consumption is lower than the winter.

The energy provided by the PV panels as well as that consumed on campus is plotted for each month as shown in Fig. 9. The contribution of this PV energy will reduce the import of energy from the grid. From Fig. 9, the PV production is 938 kWh for the whole year and energy demand is 2 595 kWh. In conclusion, the contribution of PV production in this case scenario is 36%, and this will have a considerable impact on the financial side.

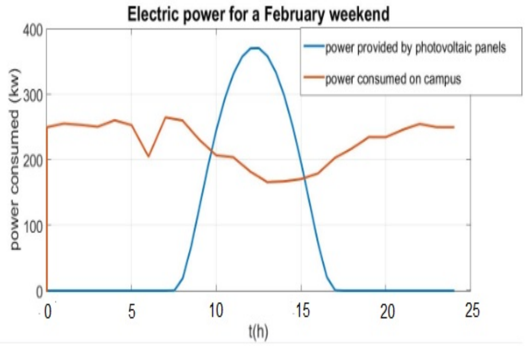


Fig. 5. Power consumption and PV generation during a weekend in February.

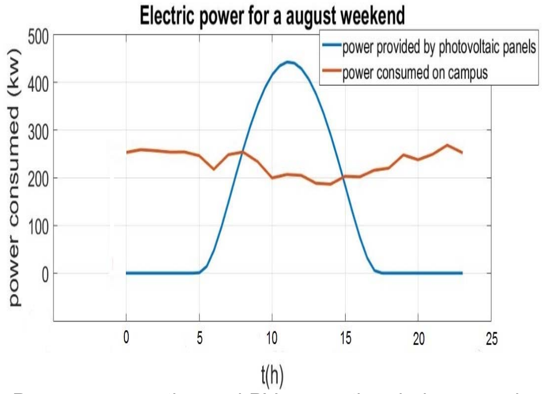


Fig. 6. Power consumption and PV generation during a weekend in August.

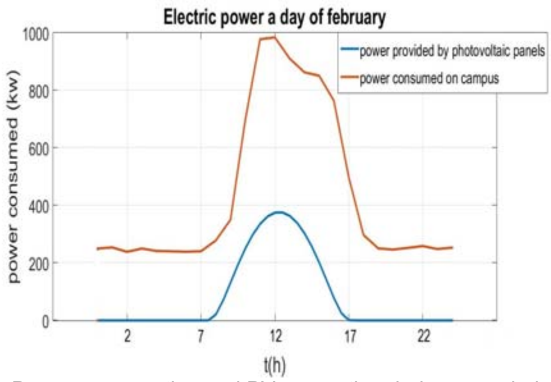


Fig. 7. Power consumption and PV generation during a week day in February.

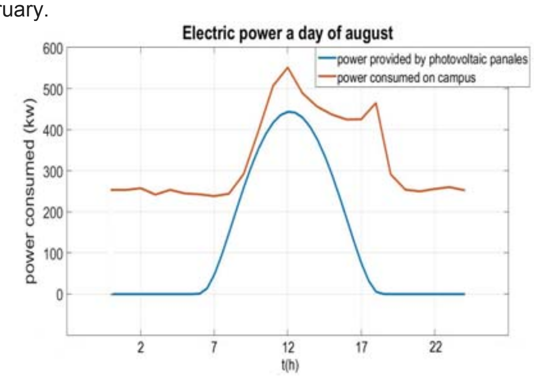


Fig. 8. Power consumption and PV generation during a weekday in August.

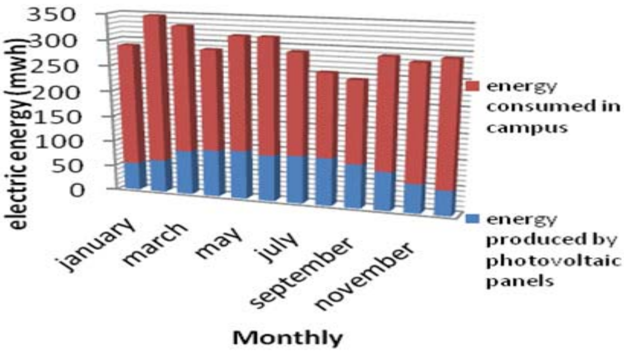


Fig. 9. Monthly PV energy production and load demand.

**Economic analysis**

Several methods are used to calculate the return on the investment. For determining the economic viability of this type of project, the net present value (NPV), the internal rate of return (IRR), the payback years (PBY) and the profitability index (IP) are the most commonly used method. These methods are analyzed in this study. The NPV as an economic indicator compares the present value of all cash flows with the present value of all cash flows associated with an investment project according to equation (1) computed at the discount rate [1,6,9,14,23,24]. The positive NPV represents an indicator of a potentially feasible project. This is the most accepted standard method used in financial evaluations for long-term projects.

(1) $$NPV = \sum_{y=0}^{Y} \frac{CF_y}{(1+r)^y} - C_0$$

where: $C_0$ – capital investment cost of the photovoltaic system, r – annual discount rate, $CF_y$ – net cash inflow for year y.

The internal rate of return (IRR) is an indicator which should be compared to an interest rate and may invalidate the NPV.IRR is solved by setting the NPV to zero, a high IRR indicates that the investment opportunity is favorable. Since it is higher than the discount rate, the PV project is considered satisfactory and interesting. The IRR is given by: [1,6,9,23,24].

(2) $$0 = \sum_{y=0}^{Y} \frac{CF_y}{(1+IRR)^y} - C_0$$

It is necessary to first calculate the annual cash flow (CF), which is the difference between the cash and the cash out, as indicated in the equation (3) [9,14].

(3) $$CF_y = Cashinflow_y - Cashoutflow_y$$

(4) $$CF_y = (C_{APSS,Y}) \times (1 - dr)^y - C_{O\&M,y}$$

where : $C_{APSS,y}$ – annual power solar saving cost at year y, dr – PV performance derating rate, $C_{O\&M,y}$ – is the annual cost of operation and maintenance at the year y.

The payback years (PBY) can be obtained by equation (5) [7,23]:

(5) $$PBY = \frac{\log(1 - \frac{C0}{CF1}.r)}{\log(\frac{1}{1+r})}$$

The profitability index (PI) indicates the amount of profit or loss that the project makes in a certain period. It is calculated by dividing the NPV value by the initial investment and adding 1, as shown in the equation (6) [1,9]. There is a break-even point when PI equals 1. When PI equals 2, the profit is doubled on the investment. The time of the investment assumed for this work is 25 years.

$$PI = \frac{NPV}{Initial investment} + 1 \qquad (6)$$

## Results and Discussions

Several parameters were considered to calculate the economic viability of the 452 kW PV system. These include the total investment cost, the fixed operating costs, of maintenance, repair and use, the price of guaranteed purchase offered by the government and the increase in energy price. So the costs of solar PV system that will produce electricity are analyzed and evaluated on the basis of Algerian's regulations. The different solar radiation for the whole year 2015 and the average annual solar radiation measured at the horizontal surface is 1 502 kWh/m$^2$ (Figs. 1 and 2). Several parameters were considered for the total production of the PV system, the energy injected into the electrical network is calculated at 604 102 kWh/year for the city of Oran. The economic input parameters are summarized in Table 4 (cost of afflation, discount and interest). The different costs used for this solar PV system are given in Table 5.

Table 5 shows that PV panels and their associated equipment are the main elements for solar PV investment and represents 70,35% or 322 228 € of the total investment which is 458 031 €. The rest of the investment will be distributed among the other equipment which will represent 29,65% (i.e. 135 803 €) of the total investment. All these costs and the different rates given in Tables 4 and 5 were used for the economic feasibility analysis of this system.

A project is considered financially feasible only if the corresponding NPV is positive. The NPV determines whether the project is generally an acceptable investment or not.

Based on the savings achieved by the PV contribution, Table 6 shows the investment cost which represents the present value of the expenditures for this year, i.e.458 031 €. The NPV is a positive value, that is, 16 304,80 €. Since NPV = 0, then the evaluation is feasible. Here, in Fig. 10, it is shown that PBY and NPV are 10,3 years and 357 079,05 € respectively over the lifetime of the PV.

The development of a PV project would be acceptable if IRR is equal to or greater than the required rate of return. the calculated IRR value for Oran is 5% higher than the discount rate. Thus, the investment considered appears profitable. The profitability index (PI) indicates the amount of profit or loss that the project makes in a certain period of time. In this case it is equal to 1,78 which is greater than the breakeven point which is equal to 1.

Table 4. Assumption of various interest rates used in the economic feasibility.

| Item description | value |
|---|---|
| Interest rate [25] | 8,78% |
| Inflation rate [26] | 6,4 % |
| Discount rate [27] | 3,75% |
| Photovoltaic panel yield loss | 0,8% |
| Initial annual system power production (kWh) | 604 011,771 |
| Project life | 25 years |

Table 5 Cost and economic assumption for the PV power plant [1].

| Item description | Cost (euro) | % of total cost |
|---|---|---|
| Feasibility study | 4 122 | 0,9% |
| Devlepoment cost | 2 748 | 0,6% |
| Engineering cost | 1 832 | 0,4% |
| Solar PV equipment | 322 228 | 70,35% |
| Other power equipment | 105 803 | 23,1% |
| Miscellaneous | 21 298 | 4,65% |
| Total initial cost | 458 031 | 100% |
| Annual operation and maintenance | 13 140 | Annual |

Table 6. Simulation results of NPV.

| Years | Cash flow(euro) | Discount rate | Present value of clash flow(euro) | Accumulated (euro) | NPV (euro) |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | -458 031 |
| 1 | 56 364,8425 | 0,0375 | 54 327,56 € | 54 327,56 € | -403 703,44 € |
| 2 | 55 808,8038 | 0,0375 | 51 847,34 € | 106 174,90 € | -351 856,10 € |
| 3 | 55 257,2133 | 0,0375 | 49 479,43 € | 155 654,33 € | -302 376,67 € |
| 4 | 54 710,0356 | 0,0375 | 47 218,76 € | 202 873,09 € | -255 157,91 € |
| 5 | 54 167,2354 | 0,0375 | 45 060,51 € | 247 933,60 € | -210 097,40 € |
| 6 | 53 628,7775 | 0,0375 | 43 000,08 € | 290 933,68 € | -167 097,32 € |
| 7 | 53 094,6272 | 0,0375 | 41 033,05 € | 331 966,74 € | -126 064,26 € |
| 8 | 52 564,7502 | 0,0375 | 39 155,23 € | 371 121,97 € | -86 909,03 € |
| 9 | 52 039,1122 | 0,0375 | 33 544,88 € | 404 666,84 € | -53 364,16 € |
| 10 | 51 517,6793 | 0,0375 | 35 651,29 € | 440 318,13 € | -17 712,87 € |
| 11 | 51 000,4179 | 0,0375 | 34 017,67 € | 474 335,80 € | 16 304,80 € |
| 12 | 50 487,2946 | 0,0375 | 32 458,23 € | 506 794,03 € | 48 763,03 € |
| 13 | 49 978,2762 | 0,0375 | 30 969,62 € | 537 763,65 € | 79 732,65 € |
| 14 | 49 473,33 | 0,0375 | 29 548,65 € | 567 312,30 € | 109 281,30 € |
| 15 | 48 972,4233 | 0,0375 | 28 192,27 € | 595 504,57 € | 137 473,57 € |
| 16 | 48 475,524 | 0,0375 | 26 897,56 € | 622 402,13 € | 164 371,13 € |
| 17 | 47 982,5998 | 0,0375 | 25 661,73 € | 648 063,86 € | 190 032,86 € |
| 18 | 47 493,619 | 0,0375 | 24 482,14 € | 672 546,00 € | 214 515,00 € |
| 19 | 47 008,55 | 0,0375 | 23 356,24 € | 695 902,24 € | 237 871,24 € |
| 20 | 46 527,3616 | 0,0375 | 22 281,60 € | 718 183,83 € | 260 152,83 € |
| 21 | 46 050,0227 | 0,0375 | 21 255,91 € | 739 439,74 € | 281 408,74 € |
| 22 | 45 576,5025 | 0,0375 | 20 276,95 € | 759 716,69 € | 301 685,69 € |
| 23 | 45 106,7705 | 0,0375 | 19 342,62 € | 779 059,31 € | 321 028,31 € |
| 24 | 44 640,7964 | 0,0375 | 18 450,89 € | 797 510,21 € | 339 479,21 € |
| 25 | 44 178,55 | 0,0375 | 17 599,84 € | 815 110,05 € | 357 079,05 € |

## Conclusion

Solar photovoltaic energy is a clean and reliable energy source. In addition, as market demand and photovoltaic system production increase the cost of photovoltaic energy technology is gradually decreasing. This study makes a comparison between the production of a photovoltaic energy and the energy consumption on the university campus of USTO. We present economic analysis of the photovoltaic generator that is connected to the local electrical network of the campus. In this paper we showed that the campus presents a high solar potential because of its high measured solar radiation. We also determine the total installed solar power. It is equal to 452 kW and represents 30% of the total power demand. The generated PV energy will mitigate the demand to the electricity supplier.

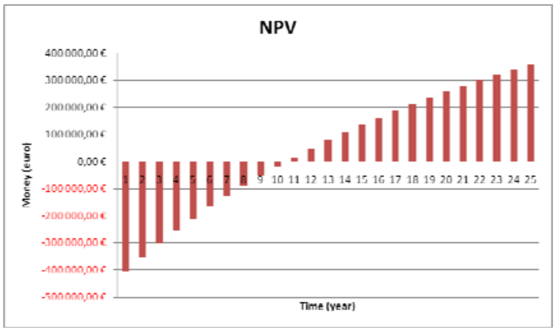


Fig. 10. NPV for the PV installation capacity of 452 kWp.

The payback year of this investment (PBY) was 10,3 which is good index for returns to cover investment costs. The average value of the internal rate of return (IRR) has been set at 5% and the profitability index (PI) is equal to 1,78, which shows that the capital budget is more appropriate for this profitable investment.

In our analysis the net present value (NPV) method is a very good way to analyze the profitability of an investment. This NPV was computed, it corresponds to positive value of 16 304,80 € and over the PV lifetime it is 357 079,05 €. This economic analysis shows that the solar photovoltaic system project at USTO campus can be considered as profitable investment with consequent financial contribution.

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## REFERENCES

[1] Yaniktepe, B., Kara, O., & Ozalp, C. (2017). "Technoeconomic Evaluation for an Installed Small-Scale Photovoltaic Power Plant". International Journal of Photoenergy, 2017.
[2] Kurzak, L. (2011). Global trends of photovoltaic energy usage. Przegląd Elektrotechniczny, 87(12b), 111-114.
[3] Moradi, H., Abtahi, A., & Zilouchian, A. (2017). "Financial Analysis of a Grid-connected Photovoltaic System in South Florida". arXiv preprint arXiv:1709.05923.
[4] J. Bebic, R. Walling, K. O'Brien, and B. Kroposki, "The sun also rises," IEEE Power Energy Mag., vol. 7, no. 3, pp. 45–54, May/Jun. 2009.
[5] European Photovoltaic Industry Association, Solar Generation V-2008. [Online]. Available: http://www.greenpeace.org/raw/content/international/press/reports/solar-generation-v-2008.pdf
[6] LIN, Chia-Hung, HSIEH, Wei-Lin, CHEN, Chao-Shun, et al. Financial analysis of a large-scale photovoltaic system and its impact on distribution feeders. IEEE Transactions on Industry Applications, 2011, vol. 47, no 4, p. 1884-1891.
[7] Gillian Basso , 'Approche à base d'agents pour l'ingenierie et le contrôle de micro-reseaux', Grade de Docteur de l'Universite de Technologie de Belfort-Montbeliard ,
[8] Fieducik, J., & Godlewski, J. (2015). Ekonomiczne i środowiskowe aspekty skoncentrowanej fotowoltaiki. Przegląd Elektrotechniczny, 91(9), 24-26.
[9] S. Rodrigues, R. Torabikalaki, F. Faria et al., "Economic feasibility analysis of small scale PV systems in different countries,"Solar Energy, vol. 131, pp. 81–95, 2016.
[10] A. Bianchini, M. Gambuti, M. Pellegrini, and C.Saccani, "Performance analysis and economic assessment of different photovoltaic technologies based on experimental measurements," Renewable Energy, vol. 85, pp. 1–11, 2016.
[11] M. S. Cengiz andM. S.Mami, "Price effciency relationship for photovoltaic systems on a global basis," International Journal of Photoenergy, vol. 2015, Article ID 256101, p. 12, 2015.
[12] article in a newspaper: "L'Algérie se lance dans un ambitieux projet de photovoltaïque", march 2017, http://www.jeuneafrique.com/417368/societe/lalgerie-se-lance-ambitieux-projet-de-photovoltaique/.
[13] article in a newspaper:" L'ALGÉRIE COMPTE DÉVELOPPER LES ÉNERGIES RENOUVELABLES" , april 2018 , http://lenergeek.com/2018/02/03/algerie-developper-energies-renouvelables/
[14] Hsu, C.-T., R. Korimara, and T.-J. Cheng, Cost-effectiveness analysis of a PVGS on the electrical power supply of a small island. International Journal of Photoenergy, 2014.
[15] S. Sowe, N. Ketjoy, P. Thanarak, and T. Suriwong, "Technical and economic viability assessment of PV power plants for rural electrification in the Gambia," Energy Procedia, vol. 52, pp. 389–398, 2014.
[16] Programme National des Energies Nouvelles et Renouvelables, Republic of Algeria ,Ministry of energy, http://www.energy.gov.dz/francais/uploads/2016/Programme-National/Programme-National-Energies-Nouvelles Renouvelables.pdf.
[17] Potentials of renewable energies in Algeria, http://www.energy.gov.dz/francais/index.php?page=potentiels
[18] Photovoltaïque : Les tarifs d'achat garantis en Algérie , JOURNAL OFFICIEL DE LA REPUBLIQUE ALGERIENNE N°23,http://www.energy.gov.dz/francais/uploads/2016/Textes_Legislatifs_et_Reglementaires/Legis_Energies_Rrenouvelables/Art2_2-Fevrier 2014_tarifs_achat_garantis_conditions_application_Elect_photovoltaique.pdf
[19] Nessim A.B., Mustapha B., Hamid B., Conception and Analysis of a Photovoltaic Microgrid in the USTO Campus, The International Conference on Electrical Sciences and Technologies in Maghreb (CISTEM 2018)
[20] Bosch Solar Module c-Si M60 ,"Haute performance et stabilité élevé",Modules solaires de Bosch Solar Energy.
[21] Temperature of the city of Oran for the year 2015 with wunderground , https://www.wunderground.com/history/airport/DAOO/2015/1/1/CustomHistory.html?dayend=1&monthend=1&yearend=2016&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=
[22] A. Verma and S. Singhal, "Solar PV performance parameter and recommendation for optimization of performance in large scale grid connected solar PV plant—case study," Journal of Energy Power Sources, vol. 2, no. 1, pp. 40–53, 2015.
[23] Chen, C. S., Hsu, C. T., & Korimara, R. (2012). The photovoltaic generation system impact on the energy demand of a small island and its financial analysis. Energy Procedia, 14, 411-417.
[24] L. B. Jose and D. Rodolfo, "Economical and environmental analysis of grid connected photovoltaic system in Spain," Renewable Energy, vol. 31, no. 8, pp. 1107–1128, 2006.
[25] Taux d'interet réel (%) Algerie , http://perspective.usherbrooke.ca/bilan/tend/DZA/fr/FR.INR.RINR.html
[26] Tendances monétaires et financières au premier semestre 2017 , taux d'inflation , BANQUE OF ALGERIA , http://www.bank-of-algeria.dz/pdf/bulletindeconjoncture_1ersemestre2017.pdf
[27] LES INSTRUCTIONS - ANNEE 2017, LE TAUX DE RÉESCOMPTE, BANQUE OF ALGERIA , http://www.bank-of-algeria.dz/html/legist2017.htm