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Towards a Sustainable Campus: Design and Evaluation of a Photovoltaic System for a Secondary School

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Abstract. The present work was developed to inform, experiment, raise awareness and disseminate information about renewable energy sources, specifically solar energy through the design of a photovoltaic system for a secondary-level educational institution in a district with development potential, which in a short time has been developed in all areas, but the lack of environmental awareness of its inhabitants forced us to take such an initiative since an academic identity must have an optimal environment for the well-being of its students and teachers, the incorporation of a photovoltaic system will not only contribute to this purpose but will also promote environmental awareness and responsibility by promoting the use of renewable and sustainable energy. The work demonstrates that it is possible to use solar energy as a source of pure, clean, and healthy energy for the use of different activities in a secondary education institution, such as entertainment, study, sports, technology, and science. The present work uses as its main support the Psis 7.2 photovoltaic installations simulation programme; this programme uses rheological and topographic data for better accuracy in data analysis. The results of this project could serve as a basis for other projects in this field since we believe that our contributions will be used for the greater good.

1 Introduction

In a world in constant evolution, educational institutions face the challenge of adapting to new demands and serving as models of sustainability and environmental responsibility. In this context, the implementation of photovoltaic systems emerges as a visionary solution that not only responds to the energy needs of these institutions but also promotes a commitment to the environment and a focus on a more sustainable future. The rising costs of energy consumption in secondary educational institutions present challenges that demand innovative and sustainable solutions. Among these institutions is the José Olaya Hualhuas State College, where the burden of high energy bills not only impacts its budget but also hinders opportunities for essential advances [1–2]. Recognizing the importance of photovoltaic systems in the educational environment transcends the simple generation of energy from sunlight. They become powerful tools to educate future generations about the importance of renewable energy sources and the reduction of the carbon footprint. In addition, these renewable energies will help reduce financial spending, so we propose the implementation of a photovoltaic system as a viable solution [3].

The purpose of this article is to show the design and potential benefits of a photovoltaic solar system at the José Olaya Hualhuas State School. The main objectives are twofold: first, to significantly reduce the institution's energy costs; and second, to promote awareness and understanding of renewable energy sources among students and staff [4].

Through a comprehensive analysis of the school's energy consumption patterns and the corresponding costs over a year, we explore the feasibility of a photovoltaic system and its potential to generate substantial savings [5]. Furthermore, we delve into the intricacies of the system design, evaluating the choice between an isolated and a grid-connected configuration. Each design is evaluated based on its performance, energy generation, and financial implications [6].

Likewise, we highlight the relevance of promoting energy related teaching in educational institutions and the potential of this innovative solar photovoltaic project to play a crucial role as an enriching educational resource [7]. By promoting an understanding of sustainable energy sources and conservation tactics, our goal is to empower students to assume the role of engaged citizens aware of their ecological environment [8].

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Ultimately, this research underscores the significance of renewable energy adoption in educational institutions, not only as an economic solution but also as a means to promote a greener and more sustainable future. By implementing a photovoltaic system at José Olaya Hualhuas State School, we envision a positive impact on the institution's financial outlook and a profound step towards shaping a more energy-conscious generation.

2 Obejctives

2.1 Problem situation

In the state school José Olaya-Hualhuas, billing costs are high and also raise awareness among students of the school about the use of renewable energy, who unfortunately do not know nor appreciate the valuable utility of such energy. The following is a table that details the cost of billing for 12 months from January to December, with the minimum amount paid of S/. 5840. The problem is that this billing consumption can be reduced, and the money saved can be used for other utilities for the school. That is why the project to design a photovoltaic system to solve the problem is presented, as shown in Fig. 1.

MONTHLY POWER CONSUMPTION		
Supply	6527393	
PERIOD	BILLING COST	POWER CONSUMPTION KW
JANUARY	180	391.82
FEBRUARY	150	326.51
MARCH	360	783.63
APRIL	750	1632.56
MAY	550	1197.21
JUNE	680	1480.19
JULY	600	1306.05
AUGUST	350	761.86
SEPTEMBER	510	1110.14
OCTOBER	480	1044.84
NOVEMBER	780	1697.87
DECEMBER	450	979.54
TOTAL	5840	112712.23

Fig. 1. Energy costs and consumption

2.2 Calculation of net value of energy consumed and battery calculation

The following Fig. 2 presents a detailed analysis of the amount of energy consumed monthly, reporting both the billing expenses for each month and the energy generated by the photovoltaic panel system.

PERIOD	ELECTRIC BILLING COST
JANUARY	180
FEBRUARY	150
MARCH	360
APRIL	750
MAY	550
JUNE	680
JULY	600
AUGUST	350
SEPTEMBER	510
OCTOBER	480
NOVEMBER	780
DECEMBER	450
TOTAL	5840

Fig. 2. Amount of energy produced by the two systems

The installation of a photovoltaic system costs 29579.21 soles; considering that the guarantee of the panels is 10 years, 5840 x 10 = 50840, thus achieving a saving of more than 5 thousand soles in bills in a year, it is concluded that in effect there is a long-term benefit.

Therefore, the battery calculations were made because it is necessary to know how much energy is required daily and also specify the days of autonomy.

Data

- Nominal battery voltage 120 V
- Depth of discharge 100% of the accumulator
- Days of autonomy 2 days
- Battery capacity 1092.83 Ah

Calculation of daily energy for 2 autonomous days, battery system capacity.

$$n°bat. \geq Vssf/Vbat \quad (1)$$

$$n°bat. \geq 60/2 \quad (2)$$

$$n°bat. \geq 30bat. \quad (3)$$

Actual daily energy =65.57 kwh/day
Usable battery capacity = 546.42Ah
Battery capacity = 1092.83 Ah

The Ultracell OPzS 2V 1120 Ultracell battery with a charge of 1120 Ah at a rate of 60 hours (c120) is selected.

1. Calculation of paneles

   Data.
   Nodes. Number of modules
   P array: Power required
   Module: Power of the module

   Number of modules = 7.59/0.4 = 20 modules.
   The area to be occupied will be 20 x 2.5m* x 1 = 600 m2

2.3 Design of an off-grid solar PV system

To solve this problem at the state school José Olaya Hualhuas, we propose the design of a photovoltaic system that reduces the cost of electricity billing to be able to invest the savings in other utilities that the school needs. This problem has two proposed solutions: the isolated photovoltaic system and the photovoltaic system connected to the grid.

A stand-alone solar PV system is an off-grid power generation system that provides the owner with energy from sunlight [9]. It usually requires the storage of the generated PV energy in solar accumulators or batteries and allows for 24-hour use [10], as shown in Fig. 3.

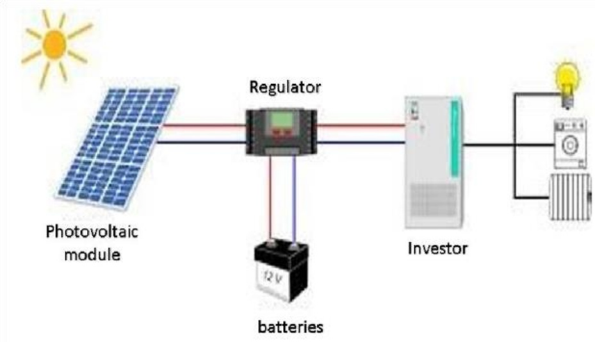

Fig. 3. Isolated photovoltaic design

2.4 Solar photovoltaic off-grid electrical design

The electrical design for an off-grid system is a direct connection to the solar panels to obtain energy without using a grid connection, as shown in Fig. 4.

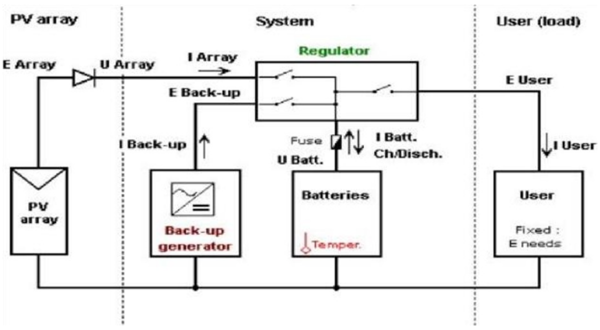

Fig. 4. Isolated circuit electrical design

2.5 Design of a grid-connected solar PV system

A grid-connected photovoltaic system is the generation of electricity by solar panels that will occur during the day, this energy will be injected for our own consumption during the day, since at night we will use energy from the grid. All this will result in savings on monthly electricity bills, Fig.5.

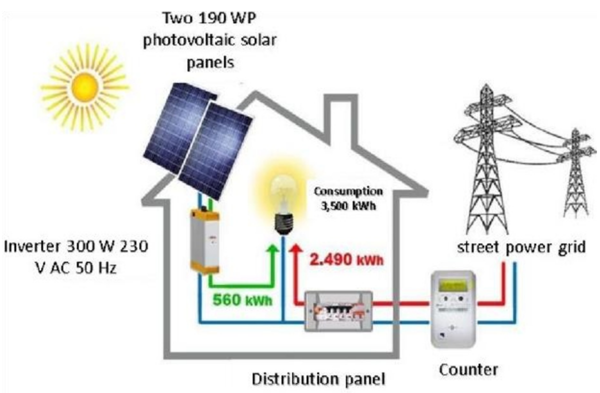

Fig. 5. Grid-connected photovoltaic design

2.6 Electrical design of a solar photovoltaic system

The electrical system is the protection connection for the house, avoiding short circuits, electrocution, or fire caused by the energy; therefore, a safe and reliable electrical system is required for the photovoltaic system, as presented in Fig. 6.

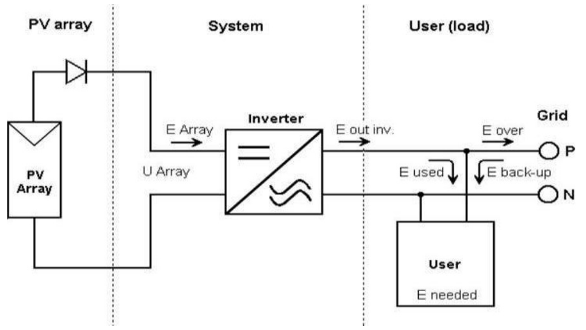

Fig. 6. Electrical design of grid-connected circuit

The location of the site was paramount for the implementation of the proposed solution, so the site was located using Google Maps for more efficiency, with coordinates of longitude -75.2567°, latitude -11.9748°, and altitude 3255 m.a.s.l., as shown in Fig. 7.

Fig. 7. Locatiion Google Maps

We used the Pvsyst 7.2 software and chose the isolated system type of project. In addition, we made the orientation of the PV module; here we entered how much will be the optimal tilt of our PV module, and we also verified that as the angle changes, the losses will increase. In our case, it is observed that there is a loss of -0.2% with respect to the tilt angle.

Therefore, given the equipment inside the school, José Olaya-Hualhuas will calculate the total demand that the PV system will require, Fig. 8.

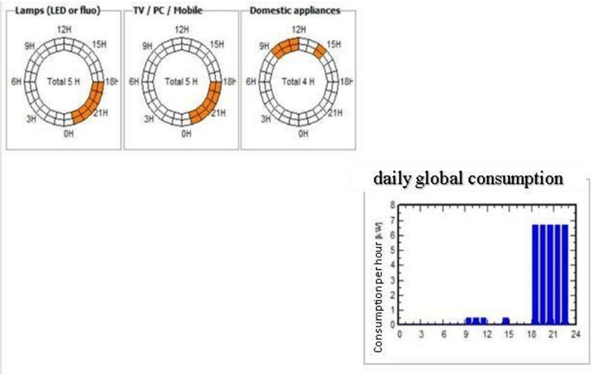

Fig. 8. Energy consumption of Colegio Olaya-Hualhuas

2.7 Comparison of photovoltaic systems

The chosen installation will be the isolated one, even though the data indicate that the grid-connected one is more efficient, as the energy provided by the grid is not used for consumption, in addition to not making use of batteries, and the energy generated in excess is injected into the grid. This last benefit is not remunerated by the company that supplies electricity, which means losses and unnecessary effort. The performance of both is very similar, but the isolated photovoltaic system means more financial savings at the end of the day, as shown in Fig. 9.

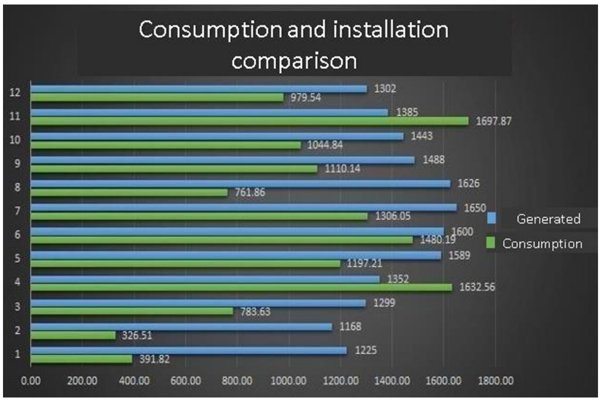

Fig. 9. Comparison of the systems

Therefore, the energy produced is more than enough to cover the costs, and considering that the population and the number of young people in the schools tend to grow, having a photovoltaic system that is larger than the consumption would be a good option for possible future expenses, Fig. 10.

313%
358%
166%
83%
133%
108%
126%
213%
134%
138%
82%
133%

Fig. 10. Energy produced in percentages

2.8 Materials and Costs for the two proposed systems

The following Fig. 11 shows the costs of the two systems, as well as the materials to be used in the two systems.

Description	Amount	Unit Price	Total price
Photovoltaic module	7	320	2240
Charge controller	1	4500	4500
Battery-Accumulators	30	870	26100
Investor	1	3480	3480
Metalic structure for modules	1	1000	1000
AW G/Kcmil 6 conductor	20	7.53	150.6
AW G/Kcmil 6 conductor	6	4.9	29.4
AW G/Kcmil 6 conductor 8	10	7.53	75.3
Fuse 100A 22 x 58	1	96.76	96.76
Fuse holder 22 x 58	2	59.42	118.84
63A 22 x 58 fuse	1	78.73	78.73
Attachable board 2 poles	2	19.79	39.58
Technical staff	1	1000	1000
TOTAL PROJECT COST			**3890921**

Fig. 11. Materials and costs of both systems

3 Results

3.1 Off-grid photovoltaic system

In the following results, Fig. 12 and Fig. 13, the bar diagram shows the usable energy and the losses in the isolated photovoltaic system.

It also shows the bars that show the system that generates electricity at 100%. There is a percentage of unused energy that marks the blue box. This is because the system is a little oversized by the days of autonomy that were considered in the calculations. We can also see that there is a loss in the batteries. This is also due to the sizing that is being given. Accumulators have a larger capacity, so there is more energy stored, which is why the software sees it as lost energy.

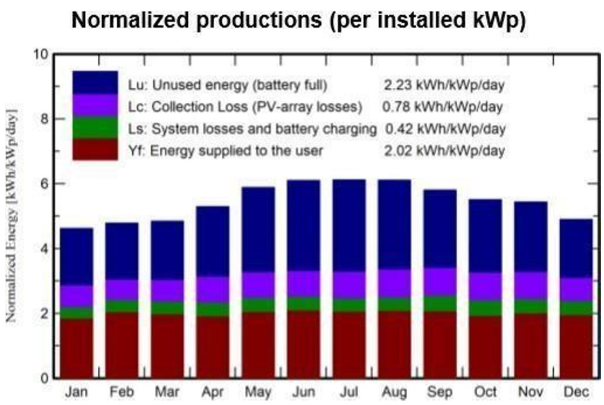

Fig. 12. Energy generated

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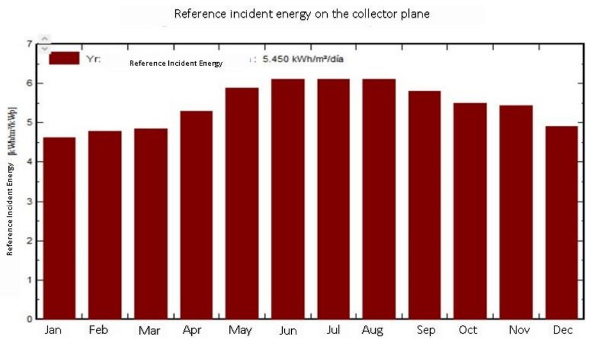

Fig. 13. Reference incident energy

In Fig. 14 below, we can see that the yield index is 0.371 and the solar fraction 0.760.

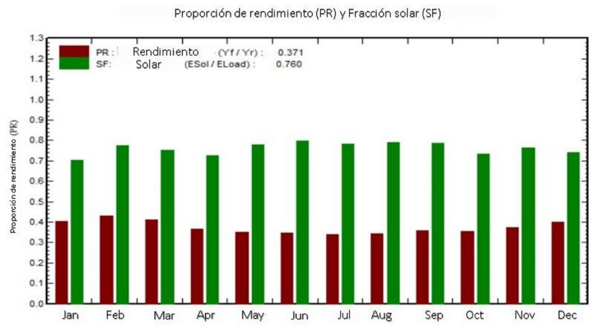

Fig. 14. Performance index

3.2 Grid-connected photovoltaic system

Of the total energy generated by the system, as in the other photovoltaic system, there are also monthly losses of 0.15 kWh/kwp/day. These losses occur in the inverter since it uses a percentage of the power for its operation, as shown in Fig. 15.

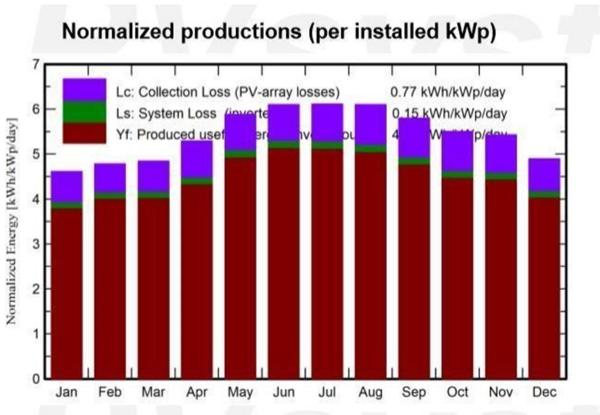

Fig. 15. Energy generated 1

Therefore, in Fig. 16, 100% of the energy generated by the PV system is shown; 16.9% of the energy is lost in the PV system, of which 14.2% is in the generator and 2.7% in the inverter.

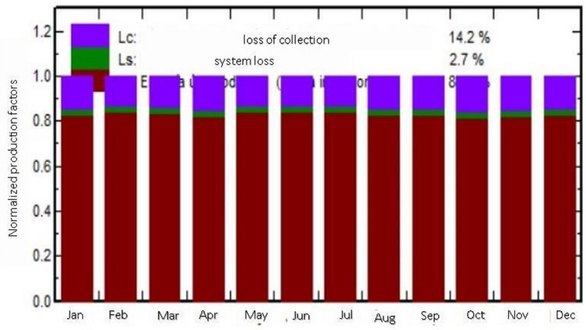

Fig. 16. Energy generated 2

3.3 Energy generated by both systems

When simulating both types of PV installations, different results were obtained with respect to each other, although this difference is small, as shown in the following table, shown in Fig. 17.

ISOLATED	CONNECTED
1.225	1097
1.168	990
1.299	1097
1.352	1061
1.589	1097
1.6	1061
1.65	1097
1.626	1097
1.488	1061
1.443	1097
1.385	1061
1.302	1097
17.128	12.912

Fig. 17. Energy generated for both systems

3.4 Cost reduction of both systems

The difference between the financial savings between these two photovoltaic systems lies mainly in the way they work, with the system connected to the grid having a lower cost reduction than the other, since when producing energy that exceeds the use, this energy is injected into the grid, and in our country this is not remunerated, this being unnecessary losses and effort, unlike its counterpart, the isolated system, which uses batteries and when assuming a lower consumption than produced, this excess energy is stored in the batteries, this being much more optimal for our purpose, as shown in Fig. 18 and Fig. 19.

ISOLATED
100%
100%
100%
83%
100%
100%
100%
100%
100%
100%
82%
100%

Fig. 18. Cost of the stand-alone system

CONNECTED TO THE NETWORK
100%
100%
100%
65%
92%
72%
84%
100%
96%
100%
62%
100%

Fig. 19. Cost of the grid-connected system

4 Conclusion

- The photovoltaic installation is a big investment, but the long-term benefits are remarkable, so it is worthwhile if you have the right advice.
- There are many factors to take into account when carrying out this type of project, such as the orientation of the sun, radiation in the area, climate, altitude, and latitude.
- In the present project, it is observed that the isolated system is more efficient; however the difference is not much, but this measure was chosen because it would be an unnecessary effort, reducing the effectiveness and efficiency of the work.
- The lifetime of a photovoltaic system is 20 to 30 years, but the supplier of these components guarantees a minimum lifetime of 10 years, which is enough to see the results of the investment.

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