Study case: cost-benefit of a photovoltaic system to reduce the consumption of the irrigation pumps in a Honduran sugar cane farm

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Abstract. This paper presents the results of the case study on the cost-benefit (B/C) of the implementation of a photovoltaic solar system on a sugar cane farm. "El Modelo's" farm, electric pumping system represents an electricity consumption of 1,087.2 (MWh/year), which translates into an expense of the 19.7%. The study is based on three analyzes: market, technical, and financial. The market analysis represents the current demand profile, this profile shows that more than 70% of the energy is consumed during the insolation time. The technical analysis is based on the interpretation of meteorological data, such as the annual global radiation representing 1,800 (kWh/m²) and a daily insolation duration of approximately 8 hours; the design of a grid-connected photovoltaic system of 4,431 (m²), with an installed power of 474.2 (kW) and the comparison of its simulation of operation between Helioscope and PVsyst, which presents an annual power generation of 686.2 (MWh). The financial analysis has the purpose of calculating the B/C, for which a leveled cost of energy (LCOE) of 0.0425 ($/kWh) is calculated, thanks to this factor a projection of the current value of savings of $ 1,009,148.71 is established, which are compared with the current value of the initial investment costs of $ 555,603.44, these values are related to establish a B/C of 1.82, which assumed that this project is profitable.

1. Introduction
Activities in the sugar industry require, among many resources, the supply of abundant water and electrical energy. For this, various technologies have been implemented to guarantee their obtaining and distribution. Irrigation in the sugar industry is an essential process that, as much as it occupies large amounts of water, consumes a large amount of energy. Less efficient irrigation systems, such as gravity irrigation, waste a large amount of water but do not consume energy. While the most efficient systems, such as the sprinkler or drip system, although they reduce water consumption, they consume a lot of energy due to their pumping system (a system that does not use gravity irrigation). The most efficient irrigation has been shown to be better for the industry, even if energy consumption increases and this generates a high economic expense. In CAHSA (Compañía Azucarera Hondureña S.A), the most important sugar industry in Honduras, there are 13,976 (Ha) of sugarcane cultivation distributed in different farms throughout the entire valley of Sula, these farms currently have a higher percentage of sprinkler irrigation systems and drip. So in order to reduce the economic expense generated by the energy consumption of the current irrigation pump system at CAHSA, a photovoltaic solar system will be designed for the “El Modelo”...
farm, which represents 664.06 (Ha), the irrigation on this farm is 100% with a drip system and represents an approximate cost of 5.7 million lempiras or $230,714.92 a year and also the consumption of 1,087.2 (MWh/year), these expenses represent 19.7% of all expenses for energy consumption of sugar cane farms. [1]

Designs and simulations will be made with HOMER Grid, Helioscope and PVsyst to carry out an analysis of the technical feasibility of the project, in addition to financial analyzes, the LCOE of the system to be carried out will be calculated and its profitability will be studied through its cost-benefit. The study will be carried out considering the precedents of photovoltaic solar systems in Honduras that have greatly helped to reduce the economic expense generated by electricity consumption in different areas.

2. Methodology and approach

2.1. Research variables
This research will be analyzed based on the cost-benefit (B/C) of the implementation of the photovoltaic solar system on the “El Modelo” farm. This variable will depend on many other independent variables such as the initial investment of the project, the generation of energy, the LCOE, and the savings from the use of the photovoltaic solar system.

2.2. Research hypothesis
The implementation of a photovoltaic solar system to cover the energy consumption of the irrigation pumps in the “El Modelo” farm, analyzing the initial investment expenses and the current value of the income for 25 years, will represent a B/C greater than 1.

2.3. Tools and instruments
In order to verify or reject the research hypothesis, different engineering tools and instruments will be used, as well as the use of Meteonorm for the analysis of meteorological data from typical years, the use of Helioscope, HOMER Grid and PVsyst for the design and simulation of the solar system, and also the use of Excel for the analysis of load profiles, LCOE and financial analysis.

2.4. Approach
For the investigation, the analysis of four main analyzes will be necessary: the study of the market that represents the farm's electrical load profile; the technical analysis that involves the design, simulation, and analysis of their results; the financial analysis that will be based on the preparation of budgets, the calculation of savings in a projection to 25 years and the calculation of the B/C.

3. Result and discussions

3.1. Market study
The research market is based on the load profile of the electric energy consumption of the “El Modelo” farm, which is analyzed from the information taken from the energy consumption meter throughout 2019. For this analysis, we will study the average day's consumption, which can be seen in Figure 1. This analysis was carried out with the help of HOMER Grid.

![Figure 1. Average day load profile.](image-url)
Based on the information of the electric load profile, it can be concluded that most of the energy consumption in “El Modelo” farm is during the period of reception of solar radiation, representing 73.92% of the total consumption, this logically is of great benefit to a solar system. The behavior of this high energy consumption during the day is since the automated irrigation system is programmed to activate the water pumps when the crop presents a need for water, this need is increased during the period of reception of solar radiation because of high temperatures and evapotranspiration.

3.2. Technical Analysis

3.2.1. Meteonorm.

Using the Meteonorm program [2], meteorological data at the location of the photovoltaic system was analyzed: “El Modelo” sugar farm, Villanueva, Honduras. The information obtained represents data on global and diffuse solar radiation, the average duration of this solar radiation, average temperatures, and average amount of precipitation.

In Figure 2 can be observed that the monthly global radiation in the locality usually averages 150 (kWh/m²) and annually reaches just over 1,800 (kWh/m²).

Figure 3 shows the average duration of solar radiation per month, which is usually exceeding 7 hours a day and reaching up to 9 hours a day.
Analyzing Fig. 4, it can be calculated that the average temperature in the area is usually 27 °C on average, although it can reach up to 35 °C in some months.

Figure 4. Average temperature.

Regarding Figure 5, it can be analyzed that during the first half of the year the rains are quite scarce, while in the second half they become more normal, although not abundant.

Figure 5. Average precipitation by month.

3.2.2. System design.
It was considered that, for this photovoltaic system on grid, the panels were used to use the Canadian Solar “CS3U-380MS” [3] which are monocrystalline and have a power of 380 (W). This decision is taken based on the solar panels that are for sale in the local market and in the cases that weigh the models with the highest power, such as some 405 (W) models, the project presents a fairly wide area for what is more convenient is the use of low-cost panels per watt, although they have less power.

Taking into account the meteorological information obtained, the nominal power of the chosen solar panel, the annual consumption of electrical energy on the farm, 1,087.2 (MWh / year) and also the percentage of energy consumption during the period of insolation, it is calculated the number of solar panels that will be used approximately for energy production that can cover 60% of the energy demand of the “El Modelo” farm, this calculation was established using the following equation [4]:

$$
\# \text{ PV panels} = \frac{\text{Energy demand}}{\text{Annual irradiation} \times \text{PV Nominal Capacity} \times \text{Losses}}
$$

Resulting in 1,239 panels, this quantity being only the basis for the actual design that will be presented below.

3.2.2.1. Helioscope simulation.
The area taken for the location of the solar system was a lot, from the farm, strategically selected for its proximity to the pumping system, also for its easy access, the absence of obstacles that cast
shadows on the system and also that the land is already owned by the sugar industry. In Figure 6 you can see the area and the projected design for the installation of the solar system, it represents 4,431 (m2) and will have 1,248 panels with a power of 380 (W), which translates into a total power of 474.2 (kW). Due to its location, the system will use an azimuth of 180° with respect to the south and the panels will also be inclined at 10°. The design was done with Helioscope. [5]

![Figure 6. Photovoltaic system’s area and design.](image)

After defining this design, the inverter to be used was chosen to consider that the pump system needs a three-phase connection of 480 (V) and, inverters that are in the local market. Based on the above considerations, the Huawei “SUN2000-36KTL” [6] inverters are chosen, which have a nominal power of 36 (kW) and an output voltage of 480 (V) three-phase. 11 inverters will be used for the system, achieving a DC / AC factor equal to 1.2, so the total AC power will be 396 (kW).

With the completed design, Helioscope generates the simulation report, thus calculating the monthly energy generation and the losses that the system may present, and calculates the performance ratio (PR), being 80.7%. Figure 7 shows the graph of expected energy generation monthly for the first year, which shows an average generation of 59.64 (MWh) per month and a total annual generation of 715.6 (MWh).

![Figure 7. Helioscope monthly energy production.](image)

In Figure 8 the losses considered by the Helioscope simulation can be seen, in which the total losses affected by 20.9% can be detected, with the losses by the temperature being the highest with 8.6%.

![Figure 8. Helioscope system losses.](image)
3.2.2.2. **PVsyst simulation.**

The design and simulation of the photovoltaic system were also carried out with the PVsyst program [7] for the comparison of results and because this is the most internationally accepted program. The simulation was performed with the same model of solar panels, inverters, the same azimuth, and inclination. This simulation has presented, like Helioscope, that the yield ratio is equal to 80% and in Figure 9 the monthly energy production can be affected, which represents an annual energy production of 686.2 (MWh).

![Figure 9. PVsyst monthly energy production.](image)

In addition, PVsyst presents its loss diagram in which two clear differences are seen with respect to that of Helioscope, with a modified consideration of 5% of soiling loss is taken since in the sector the cultivation of sugarcane will generate dirt. considerable, and as can be seen in Figure 10 PVsyst considers a greater loss by temperatures with 10.11%, the sum of all the losses is equal to 21.87%.

![Figure 10. PVsyst system losses.](image)

Comparing the two simulations they do not differ much; the difference is that PVsyst takes 1% more losses in the system and this can answer why the annual generation of PVsyst is less than 30 (MWh). For the rest of the analysis, the information obtained from the PVsyst simulation will be used, because it is the most internationally reliable program.

3.2.3. **Financial analysis.**

The purpose of this analysis is to calculate the cost-benefit (B/C) of the project, so a savings projection can be done for the 25-year life of the project, comparing the cost of energy consumption with the rated current and the cost that would represent energy consumption with the LCOE, which was calculated with the following equation [8]:

\[
LCOE = \frac{\sum_{n=0}^{m} \frac{\text{Capital Cost}_n + \text{O&M}_m + \text{Fuel Cost}_m}{\text{Energy Demand}_m}}{\text{Energy Demand}_m}
\]
For the financial analysis, the following parameters presented in Table 1 were considered.

**Table 1. Principal parameters**

| Parameter                                      | Value       |
|------------------------------------------------|-------------|
| Load Capacity (kWp)                            | 474.20      |
| Specific capital cost ($/kWp)                  | 1,060.87    |
| Annual inflation rate (%)                      | 1.5%        |
| Increase in annual rate (%)                    | 1.5%        |
| O&M costs ($/kW*año)                           | $19.00 [9]  |
| Total capital cost ($)                         | $504,060.08 |
| Tax rate / income tax (%)                      | 25%         |
| Insurance ($)                                  | $6,365.20   |
| Project lifespan (years)                       | 25          |
| Average weighted capital cost (%)              | 9.55%       |
| Energy generated per year (kWh/year)           | 686,120     |
| Annual depreciation (%)                        | 0.5%        |
| Dollar to Lempira exchange rate                | 24.97       |
| Current energy rate (Lp/kWh)                   | 5.1945 [10] |
| Current energy rate ($/kWh)                    | 0.2080      |

The total capital cost value represents the initial investment of the project and was calculated with the budget in Table 2.

**Table 2. Investment budget in dollars**

| Item                              | Amount   |
|-----------------------------------|----------|
| Photovoltaic panels              | $118,560.00 |
| Solar inverters                  | $44,000.00  |
| Electrical wiring                | $99,936.25  |
| Support structure                | $83,496.50  |
| Civil work                       | $60,000.00  |
| Grounding system                 | $51,615.17  |
| Combiners                        | $7,473.00   |
| Controllers                      | $16,989.10  |
| Measuring system                 | $5,393.06   |
| Workforce                        | $16,597.00  |
| Total                            | $504,060.08 |

With these parameters the LCOE of the photovoltaic system has already been calculated, being equal to 0.0425 ($ / kWh) and from this value the savings represented by the use of the system and after this the current value of this savings, in addition to the flow, were calculated accumulated savings, the graph of the investment recovery period could be established, as can be seen in Figure 11, the investment will recover in just over 3 years and a total saving of 3.6 million dollars, which represents 90.3 million of lempiras. These values were calculated in an Excel book.
With the data obtained, it was already possible to calculate the current values of savings (VS) and the current value of initial investment (VII), which in turn allowed the calculation of B/C, which is equal to the VAI ratio between the VAC. In addition, the internal rate of return (IRR) was calculated, as can be seen in Table 3.

### Table 3. Investment budget in dollars

| Return on investment (years) | 3.08  |
|-----------------------------|-------|
| CVS ($)                     | $1,009,148.71 |
| CVII ($)                    | $555,603.44 |
| C/B                         | 1.82  |
| IRR (%)                     | 31%   |

The value of the B/C can be interpreted in two ways, if the quotient is less than or equal to 1, the project is considered to be unprofitable and, on the contrary, if the quotient is greater than 1, the profitable project is considered.

### 4. Conclusions

The research hypothesis was verified by calculating that the B/C of the installation of this photovoltaic system is 1.82 and because this ratio is greater than 1, it can be concluded that the project is profitable, and its savings represent a benefit over the cost for the initial investment. The consumption of the water pumps of an irrigation system for sugar cane is mostly during the day, exceeding 70% of daily consumption, so solar systems are of great benefit to this sector. The on-farm photovoltaic system "El Modelo" represents a saving in 25 years equivalent to 3.6 million dollars, which represents a 62% savings compared to the costs of continuing with the current system and concludes that the investment may be recovered in just over 3 years. Any sugar industry or even other agro-industries with high consumption by electric irrigation pumps can take advantage of photovoltaic solar systems to save the economic expense that such consumption represents.

### 5. References

[1] CAHSA. (2018). Manual de Calidad. Villanueva.
[2] CREE. (2019). Historial de tarifas. Obtenido de https://www.cree.gob.hn/historial-de-tarifas/
[3] Canadian Solar Inc. (2018). KuMax HIGH EFFICIENCY MONO PERC MODULE CS3U-375|380|385|390|395MS. Ontario.
[4] Gamboa, Y. X. (2014). Sistema de riego por goteo con módulos solares. Alajuela.
[5] Folsom Labs. (2019). Helioscope. Obtenido de Folsom Labs: https://www.helioscope.com/
[6] Huawei. (2019). SUN2000-36KTL Smart String Inverter.
[7] PVsyst. (2020). PVsyst. Obtenido de https://www.pvsyst.com/
[8] Villatoro Flores, H., Furubayashi, T., & Nakata, T. (2015). Decentralised electricity generation system based on local renewable energy sources in the Honduran residential sector. Sendai. 10.1007/s10098-015-1067-x

[9] NREL (2016). Distributed Generation Renewable Energy Estimate of Costs.

[10] CREE. (2019). Historial de tarifas. Obtenido de https://www.cree.gob.hn/historial-de-tarifas/

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