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Research Article

Technical-Economic Analysis of a Hybrid System with Renewable Sources

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ABSTRACT

The objective of this work was to develop a methodology that allows to perform a technical economic analysis of a hybrid system with renewable energy sources, as well as to evaluate both the technical feasibility and the economic profitability of implementing them in a specific location and in this way determine if the system is technically viable and if its implementation is economically possible.

The aim is to determine whether the installation of a hybrid system in the Crucita Parish of the Portoviejo canton is a technically and economically viable option. These types of systems, which combine solar energy with other renewable sources, can provide a sustainable energy source and contribute to the reduction of greenhouse gas emissions.

Subsequently, the Homer Pro program will be used to design the relevant simulation, which will allow us to introduce data such as electricity demand input, available natural resources and technologies in which we can study how various combinations of renewable systems respond to electricity needs.

According to the technical economic analysis, the implementation of a hybrid system that generates energy through renewable sources in the Crucita parish is a viable and advantageous alternative. This system would reduce energy costs in the long run and help take advantage of available renewable resources.

In addition, the project would have a favorable social impact by promoting local development and improving the quality of life of the community. The findings support the implementation of clean and sustainable energy as part of a comprehensive strategy to move towards a more responsible and sustainable energy future in the Crucita Parish of the Portoviejo canton.

Keywords: Hybrid system, economic feasibility, sizing, renewable energy resources.

INTRODUCTION

The transition to clean and renewable energy sources is essential to ensure a sustainable and resilient energy future in a world where sustainability and climate change mitigation have become global priorities [1]. In this context, the Crucita Parish of the Portoviejo canton stands out for its rich biodiversity and its high potential for the use of renewable resources, such as solar radiation and favorable winds [2].

This region has optimal geographical and climatic conditions for the generation of energy from renewable sources, which would not only reduce dependence on fossil fuels, but also mitigate the adverse environmental effects associated with them [3]. The present study aims to thoroughly evaluate solar radiation and wind speed in Crucita, as well as current use and future energy forecasts, in order to adequately size a hybrid distributed generation system.

Hybrid systems, which combine multiple energy sources in a single installation, have proven to be a viable alternative for electricity supply in isolated communities [4]. Using tools such as HOMER PRO, the optimal configuration of the hybrid system in economic and environmental terms will be evaluated [5]. This analysis will include the costs of procurement, installation, operation and maintenance of system components, as well as the possibility of selling surplus energy to the local power grid [6].

In addition, environmental benefits, such as the reduction of greenhouse gas emissions and the reduction of the carbon footprint, and social benefits, such as the creation of local employment and the promotion of technological and educational development in the community, will be examined.

The objective of this study is to determine the technical and economic feasibility of implementing a hybrid system with renewable energy sources in the Crucita Parish, considering technical, economic and environmental aspects. This analysis aims to encourage the adoption of clean energy, promote sustainable development and improve the well-being of the local community, while preserving natural resources for future generations.

METHODOLOGY

The design of this research project was based on a mixed sequential methodology composed of two phases. In the first phase, a qualitative research design with a descriptive scope based on documentary and interview modalities was used to characterize the sector, the electricity system and the details of current consumption. In the second, the demand profiles, the analysis of the available renewable energy resources, the design of the microgrid and the financial viability analysis of the different scenarios proposed were built through a quantitative research design and descriptive scope.

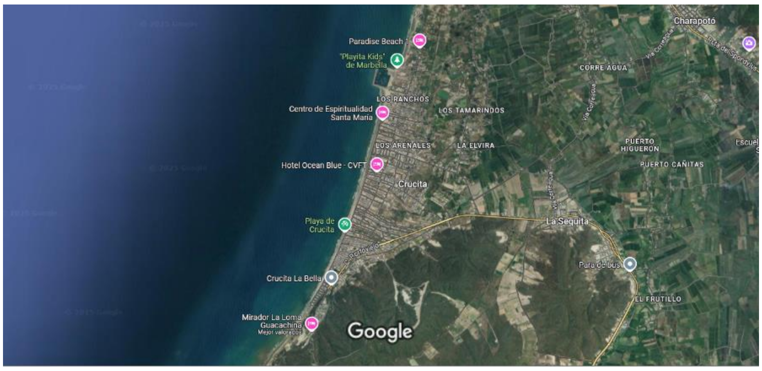
The HOMER PRO software will be used, which is a tool designed to determine the best way to implement a simple or hybrid micro-grid using a variety of energy sources [7] [8]. In the case of analysis, a hybrid wind-solar microgrid was proposed that would depend on the grid only in case of emergency and would work with solar panels, and turbines.

To design a technical solution, the collected data is used and combined with the analysis of environmental, socio-cultural, economic and technical criteria, including energy resources. The affordable and sustainable energy system must meet the needs of the community and reduce any negative social, cultural or environmental impacts.

Study area

In the case study, the location corresponds to the Crucita Parish of the Portoviejo canton.

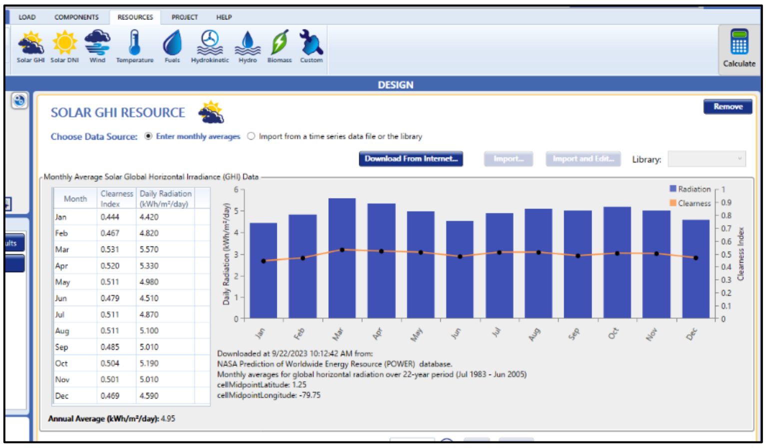
Figure 1. Location of the hybrid system.



System Configuration

The software provides approximate values of the Solar Resource (RHG) in the desired locations. The data generated represents monthly averages in the specified areas. The "Resources" option can be seen at the top of Figure 6, where several download options are located, in this case study, "Solar GHI" will be used.

Figure 2. Selection box of the resource to be used and average solar incidence.



To proceed with the design, it is essential to determine the required electrical load. To be even more specific, it collects data to identify the peak and off-peak hours of consumption, which will allow a more accurate calculation of the microgrid.

Figure 3 shows the choices allowed in the "load" option and indicates in detail the profiles with which it can be worked, through this option the case study will be selected which will be load 1 in which it can include the reference data that will be in this case of 24 hours in the 12 months of the year.

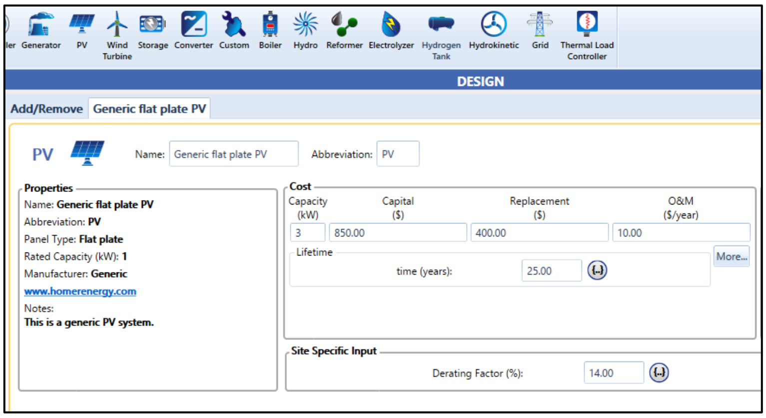
Figure 3. Load selection box.

Once the required load has been determined, the components that will be used to meet the electrical demand mentioned above are selected. In this case of analysis, photovoltaic energy and wind energy will be chosen.

The software comes with pre-installed panels. However, in some cases, manufacturer data is missing for certain options, adding a layer of complexity to the design process. It should be noted that there are two generic options available. These options can be modified to replace the selection data in the panel.

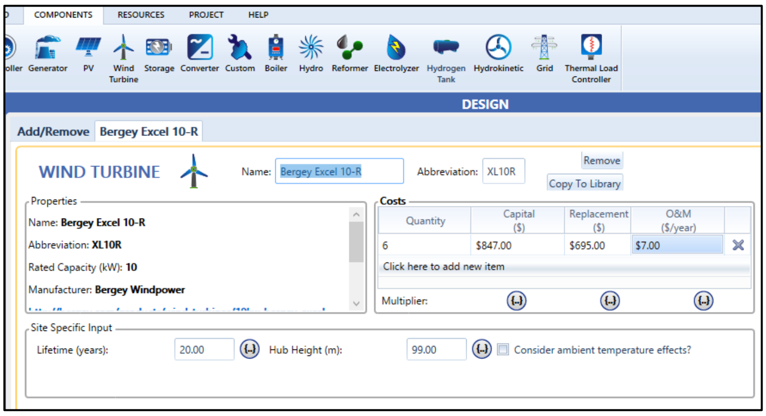
By choosing either option, the desired values can be incorporated to meet the required demand, as shown in Figure 8. Data on cost, capacity in kW, price per kW, equipment replacement cost, and operation and maintenance cost are entered.

Figure 4. Solar Panel Selection with Generic Options.



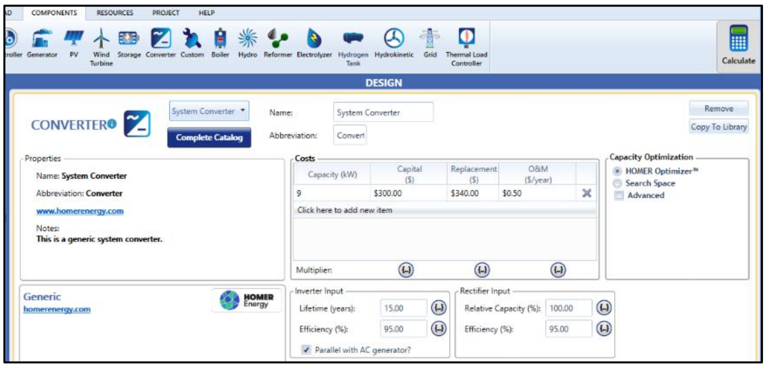
We also proceed with the wind turbine, in this case a Bergey Excel 10-R turbine was chosen as shown in Figure 5, in the same way data is entered regarding the cost, the capacity in kW, the price per kW, the cost of replacing the equipment and the costs of operation and maintenance.

Figure 5. Selection of the Bergey Excel 10-R Turbine.



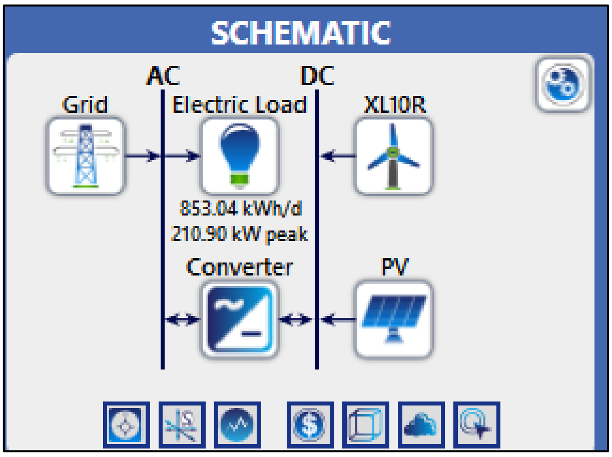
The process of selecting the converter or charge inverter continues, taking into account the total power of the system. The component window is chosen, and the converter is selected, as shown in Figure 6. In addition, a drop-down list of converters with different power capacities is available. In this specific case, a generic converter was chosen, as it is the one that best suits the needs of the system. The box also contains boxes to fill in the required data.

Figure 6. Converter selection.



The process of selecting each of the components necessary to design a hybrid system with the software comes to an end as can be seen in Figure 7. It is clear that there is the possibility of entering various data to obtain a more precise solution.

Figure 7. Hybrid wind-solar generation system completed.

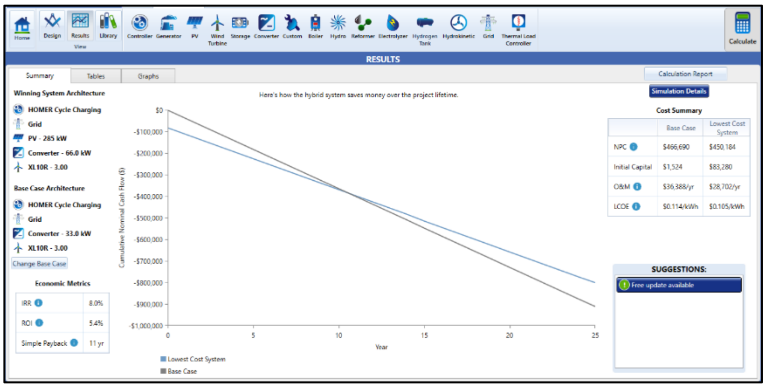


ANALYSIS AND DISCUSSION

The goal of the project was to develop a step-by-step process using HOMER software to analyze two potential scenarios to meet the electricity demand of lighting at the previously defined location. The simulations recreated various factors to determine the most feasible configuration. The simulation results, based on the given specifications, provide a clear view of the costs associated with deploying a hybrid system using a solar panel and a wind turbine as primary resources, backed by the grid only for emergencies.

An overview of the winning system is provided in this part of the results: the system with the lowest net present cost compared to the base system, the system with the lowest cost of capital as shown in Figure 8.

Figure 8. Overview of the winning system.



Economic metrics

This result compares the economics of the winning system to the base case system and lists the Internal Rate of Return (IRR), Return on Investment (ROI), and Simple Return. In this case the internal rate of return has a current cost of 8% this value represents the difference of the two flow sequences, the return that in this case would represent the annual cost savings in relation to the initial investment that was proposed which was 5.4%, finally, we will have the reimbursement or recovery that was indicated the time it will take to recover the difference in the investment costs that we will have to be 11 years as indicated in Table 1.

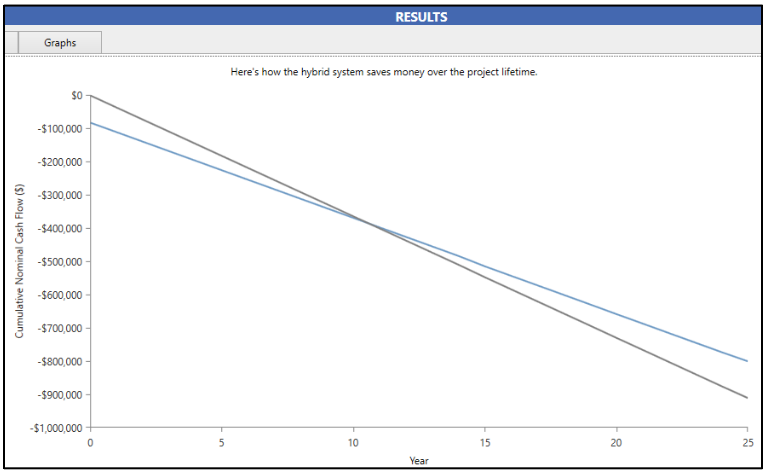
Table 1. Economic metrics of the system.

Economic Metrics	
IRR	8.0%
ROI	5.4 %
Simple Refund	11 years

Lifetime Cash Flow Graph

Figure 9 shows how the hybrid system saves money over the life of the project: the nominal cash flow accumulated over the life of the project. The blue line is the winning system and the gray line is the base case system. Simple recovery in years occurs when the two lines intersect and are highlighted with the black line in the raft.

Figure 9. Cash flow over the life of the project.



Total Cost

In this section of the results, he offers a comparison between the costs (initial, operational, and energy cost) of both the base case and the lowest cost/winning system. What is observed in table 4 are Net Present Cost (NPC) values in which a value of $466,690 was obtained for the base case and for the winning system that determined the program was $450,184, in the Initial Capital for the base case an initial value of $1,524 was proposed compared to $83,280 of the lowest cost system, in terms of Operation and Maintenance costs for the base case $36,388/year and the lowest cost system $28,702/year, finally the levelized energy costs are lower in the case of the lowest cost system. In total, the costs of the winning or lower-cost system are more favorable and provide better viability for the realization of the system.

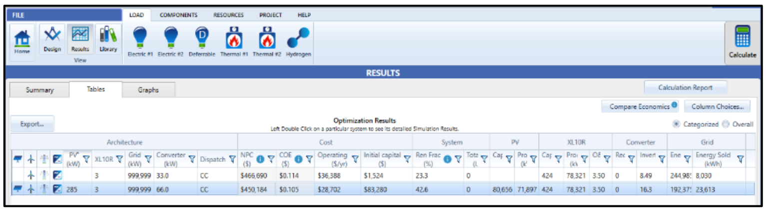
Table 2. Total cost of base case and lowest cost system.

	Base Case	**Lowest Cost System**
NPC	$466,690	$450,184
Initial Capital	$1,524	$83,280
O&M	$36,388/year	$28,702/year
LCOE	$0.114/kWh	$0.105/kWh

Details of the Lowest Cost Simulation

The lowest cost and most optimal system for this hybrid system this time will be the system made up of all the elements that was proposed when selecting the hybrid system as shown in Figure 10 in this section you can find the costs generated by each component used in its entirety such as a solar panel, a wind turbine, a converter and the electricity grid.

Figure 10. Results of the simulation.



Cost Summary

This tab will primarily show cash flows as present value or annualized cost, categorized by component or cost type. By cost type has HOMER classify costs according to type: capital, operation and maintenance, replacement, resources, and salvage value as shown in Figure 11. HOMER categorize costs by both component and type in a single chart.

Figure 11. Cost Summary

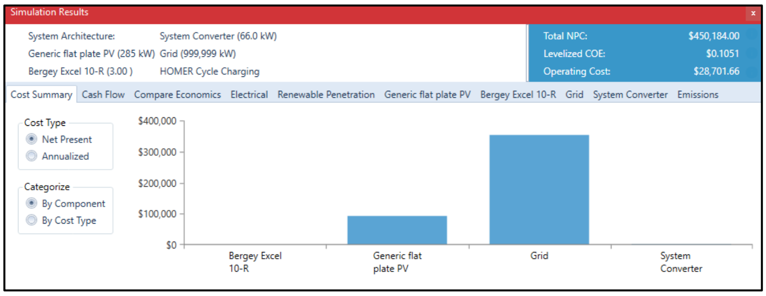


Table 3 below the chart shows the cash flow summary broken down by component and cost type. The Bergey Excel 10-R wind system will have a total cost of $515.87, the Generic flat plate PV solar system of $92,785.54, for the electrical grid it will have a total value of $353,787.01 in what involves the converter this will have a value of $3,095.56 finally the total system will have a value of $450,183.98.

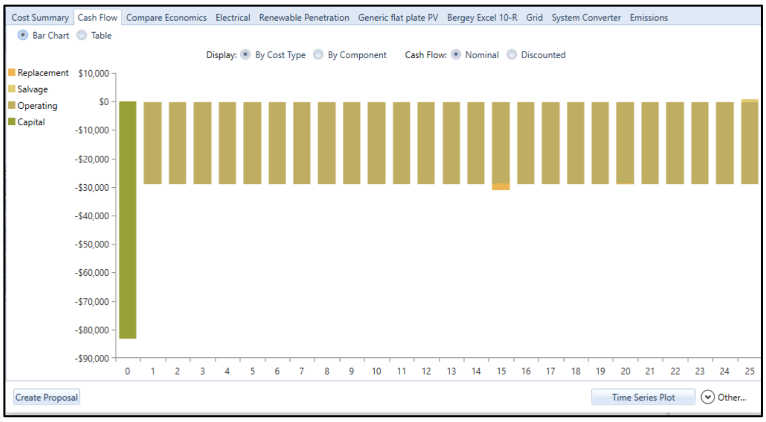
Table 3. Cash flow summary broken down by component and cost type

Component	Investment ($)	Replacement ($)	O&M ($)	Fuel	Ransom ($)	Total ($)
Bergey Excel 10-R	$423.50	$108.35	$44.74	$0.00	$-60.73	$515.87
Generic flat plate PV	$80.655.56	$0.00	$12,129.98	$0.00	$0.00	$92,785.54
Grid	$0.00	$0.00	$353,787.01	$0.00	$0.00	$353,787.01
System Converter	$2.201.39	$1,041.04	$49.90	$0.00	$-193.77	$3,095.56
System	$83.280.44	$1,149.39	$366,008.64	$0.00	$-254.50	$450,183.98

Cash flow

This section shows the cash flow of the system in graphical or tabular form. Each bar in the chart represents a total inflow or total outflow of cash during a single year. The first bar, for year zero, shows the capital cost of the system, in this case it will have a cost of $83,280.44, the system per year will generate an approximate value of $28,631.65 per year operating and after 15 years a replacement cost of $2,494.91.

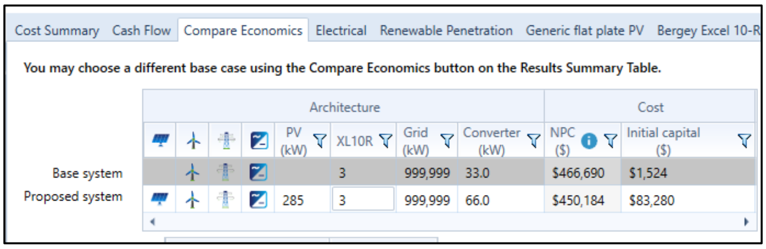
Figure 12. Cash flow of the system in graphical or tabular form.



Economic comparison

In this part of the results, the opportunity is given to evaluate the economic advantages of the current system compared to a reference system. Figure 13 shows the comparison against a possible case and Table 4 of economic metrics.

Figure 13. Economic comparison.



These metrics show what are economic measures as indicated in Table 4, which represent the value of the difference between these two systems, as first we have the current value of $16,506 which indicates how much money would be saved during the life of the project compared to the base case, then we have the current value of $1,291 per year, a return on investment of 5.4%, an internal rate of return of 8% and finally a recovery of how long the difference in investment costs will take.

Table 4. Economic metrics - case comparison.

Metric	Value
Current Value ($)	16,506
Annual value ($/yr)	1,291
Return on Investment (%)	5.4
Internal rate of return (%)	8.0
Easy Recovery (yr)	10.59
Discounted Recovery(yr)	17.52

Photovoltaic outputs

Figure 14 shows that the panel starts working from 6 am to 6 pm, and during this period of time it shows its maximum power between 11 am and 2 pm, represented by the color yellow. On the other hand, the blue color represents the lowest power of the panel throughout the year.

Figure 14. Generic flat plate photovoltaic power (kW).

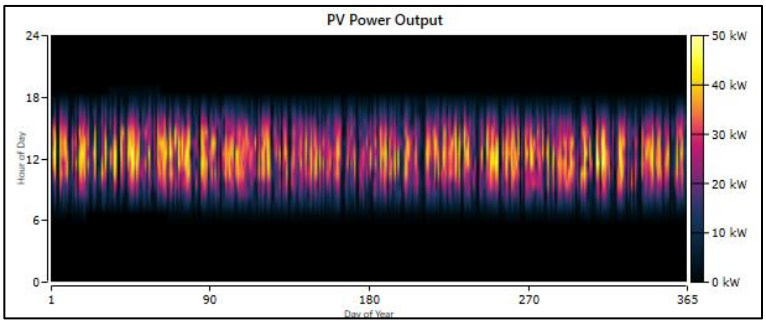


Table 5 shows a small summary of what the photovoltaic generation of the hybrid system has done, which through the solar panels will have a nominal capacity of 285 kW, an average output of 8.21kW, an average output per day of 197kW/d, in addition to what is a capacity factor of 2.88% which offers a total production of 71,897 kWh/year.

Table 5. Generic flat plate photovoltaic statistics.

Quantity	Value
Fare Capacity	285 kW
Average output	8.21kW
Average output	197kW/d
Capacity factor	2.88 %
Total production	71,897 kWh/year

Wind turbine outputs: Bergey Excel 10-R

The visual representation in Figure 15 reveals continuous generation throughout the day for the first 150 days of the year. During this period, generation remains low, ranging from 0 to 7 [kW]. However, from day 151 to day 270, wind generation peaks. In this period, generation ranges from 7 to 28 [kW].

Figure 15. Bergey Excel 10-R Power (kW).

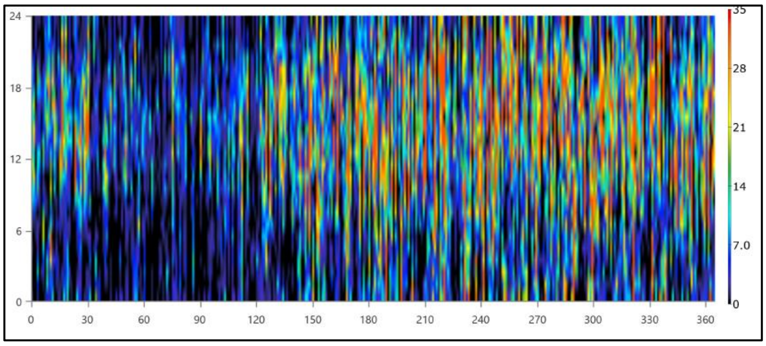


Table 6 presents an overview of wind generation in the hybrid system, which will have a total nominal capacity of 30 [kW] through the wind turbine. The average production is 8.94 [kW], and it has a capacity factor of 29.8%, resulting in a total of 78,321 [kWh/year].

Table 6. Bergey Excel 10-R statistics.

Quantity	Value
Total Rated Capacity	30.0 kW
Average production	8.94 kW
Capacity factor	29.8 %
Total production	78,321 kWh/year

Network Outputs

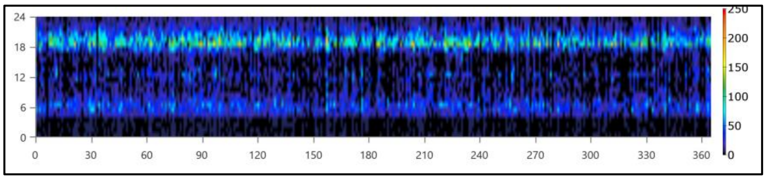
Table 7 shows details of the purchase and sale of electricity to and from the grid, and the resulting costs in different months of the year. Annual would have a total cost of energy purchased from the grid of 192,375 Kwh, in energy sold to the grid a total of 23.61 kWh, net electricity purchased from the grid of 168,762 Kwh, a maximum demand for energy served by the grid of 203 kWh and the total amount paid in energy charges $27,675.

Table 7. Buying and selling electricity.

Month	Purchased Energy (kWh)	Energy Sold (kWh)	Net Purchased Energy (kWh)	Maximum demand (kWh)	Energy charge $
January	17,418	1,730	15,688	186	$2,526.16
February	15,969	902	15,067	158	$2,350.24
March	20,114	756	19,358	189	$2,979.28
April	18,119	882	17,237	192	2,673.71
May	15.282	1,948	13,334	163	2,194,91
June	15,849	1,975	13,874	173	2,278.63
July	15,186	2,559	12,627	194	2,149.91
August	16,919	2,383	14,536	182	2,418.69
September	14,637	2,363	12,274	174	2,077.37
October	13,245	2,573	10,672	168	1,858.10
November	13,810	2,973	10,838	203	1,922.92
December	15,827	2,568	13,259	151	2,245.69
Annual	192,375	23,61	168,762	203	27.675.60

Figure 16 shows the energy input from the electricity grid that the system acquires, representing the 365 days of the year (horizontal axis) and the 24 hours of the day (left vertical axis), showing the amount of energy (right vertical axis) that is taken from the grid. It is observed that the system takes energy from the grid mainly during periods when solar energy production is insufficient (from 0:00 to 6:00 and from 18:00 to 24:00). In this case, it can be said that the power grid behaves similarly to a battery.

Figure 16. Energy purchased from the grid (kW).



The surplus energy generated by PV panels can be used by selling it to the power grid. HOMER is also exploring the possibility of selling this energy, providing insight into how it would be integrated into the electricity grid. The energy that could be sold is mainly produced during midday and surrounding hours, when solar radiation is at its highest.

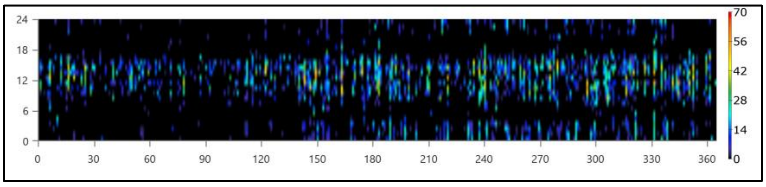


Figure 17. Energy sold to the grid (kW).

Monthly averages of total renewable energy production

The renewable energy production of the hybrid system is examined for each month of the year in Figure 18. September is noted to have the highest annual energy peak with 79.82 kW. In addition, Figure 19 reveals that March has the lowest annual maximum energy, of 66.13 kW.

Figure 18. Maximum monthly renewable energy production.

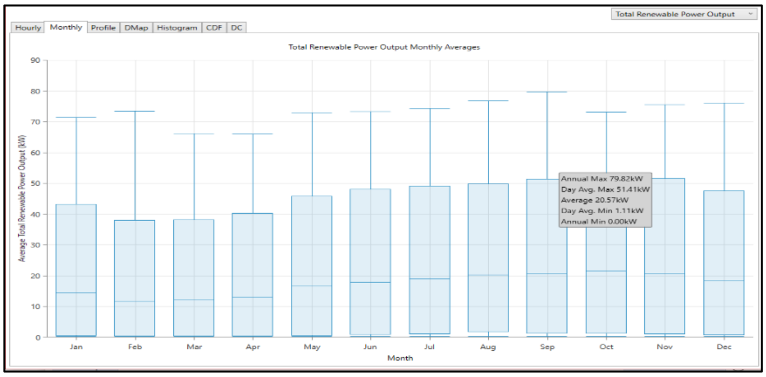
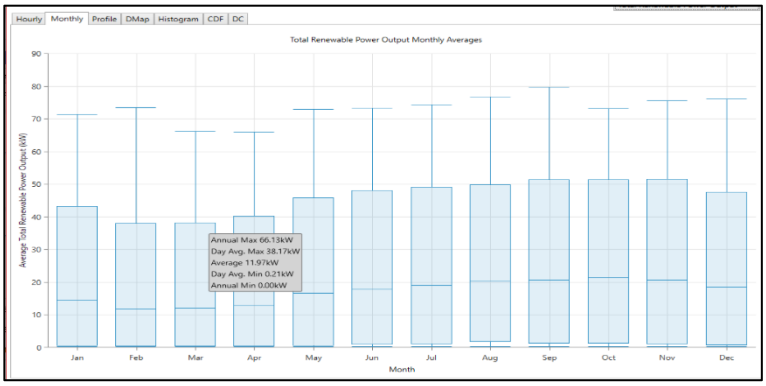


Figure 19. Minimum monthly renewable energy production.



Emissions

Finally, HOMER also produces pollutants by consuming electricity from the grid. It is crucial to mention that certain pollutants are directly related to the type of energy generation source (thermal, nuclear, hydroelectric, etc.), which is distributed to users through the electricity grid. Table 8 provides the values in kg per year of the pollutants generated by this type of systems such as carbon dioxide which has generated 121,581 kg/year, sulfur dioxide with 527 kg/year and sulfur oxide with 258 kg/year.

However, when it comes to Ecuador, where most of the energy supplied to the grid is generated through hydroelectric plants, a more accurate estimate of the GHG generation of the proposed system would have to be made, which is outside the scope of this study.

Table 8. Greenhouse gases generated by a grid-connected system.

Quantity	Value (kg/year)
Carbon dioxide	121,581
Carbon monoxide	0
Unburned hydrocarbons	0
Particulate matter	0
Sulphur dioxide	527
Sulphur oxides	258

CONCLUSIONS

It can be concluded that after the technical and feasibility study carried out in this work, that the parish of Crucita has a wide energy potential for the use of these renewable energies through the proposed hybrid system, since its geographical area provides adequate accessibility for the installation of said system.

The optimization systems are classified based on the NPC, and the economic values are calculated to supply energy to the homes and determine the optimal net present cost (NPC), this time the results of our case study using HOMER indicate that the optimized initial capital cost is $83,280, the net present cost is $450,184 and the cost of energy is $0.115 kWh. The price of the optimal system energy is lower than the cost of the energy supplied by the grid. Although the initial cost of solar-wind energy is high, it offers electricity at a lower cost.

Through the simulation in the Homer Pro program of the hybrid system, it was acquired that the amount of energy that the system will produce will be 342,593 kWh/year, which indicates that each element of the generation system contributes significantly to the rational use and production of clean energy.

From the results obtained, it was determined that it is not essential to use the different types of renewable resources of the parish for the system to satisfy all the electricity demand of the Crucita sector, since when a solution or case is generated that only uses the wind resource, we will see that the difference lies mainly in the cost of the energy generated (COE) for each kWh that this hybrid system will have.

The system determined that it is possible to meet the electricity needs of the different homes only with renewable energy sources without increasing the current value of the cost of electricity, likewise the use of only clean sources significantly increases the initial investment of the proposed project.

Last but not least, the positive internal rate of return and net present value demonstrate that the realization of the hybrid generation system project under the architecture and design has been considered considerably attractive in the economic field for the sector.

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