Off-Grid Wind-Solar Hybrid Energy System for Analaitivu Island in Sri Lanka

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ABSTRACT

The objective of this project is to implement an off-grid wind-solar hybrid energy system with a battery bank system for Analaitivu island in Sri Lanka, which has no connection to the main grid. The hybrid model is developed by analyzing the wind-solar weather pattern of the island to fulfill the energy demand by choosing the ideal combination of solar cells and wind generators.

KEYWORDS: *Wind-Solar Hybrid Energy System, Battery Bank System, Off-grid Energy System, Analaitivu Island, Northern Province, Sri Lanka.*

1 INTRODUCTION

Wind-Solar hybrid systems that are used for rural residences are stand-alone systems that operate "off-grid" and are not connected to an electricity distribution system. When solar and wind power resources are used together, reliability is improved, and the continuous system energy service can be enhanced with the battery storage system. When compared to other forms of renewable energy, such as biomass and hydro, solar and wind power stand out for their abundance and limitless potential, as well as the absence of any costs associated with their acquirement.

Islands of Nagadeepa, Delft, Analaitivu, and Eluvaithivu in the northern province of Sri Lanka are primarily recognized as being isolated from the main grid. Eluvaithivu island has already implemented an off-grid wind-solar and diesel generator system. This project proposed an off-grid wind-solar hybrid energy system with a battery bank system for Analaitivu island. The system is capable of fulfilling the power and energy demand of the entire island in an economically viable manner. As a result of Sri Lanka's ongoing political, economic, and energy crisis, people have recently experienced more than 10-hour power cuts. The proposed wind-solar hybrid strategy can also be used in other rural areas of Sri Lanka to address this serious problem.

2 SOLAR AND WIND ENERGY POTENTIAL IN THE NORTHERN PROVINCE

2.1 Site selection

Data was collected from the Ceylon Electricity Board (CEB) on the main islands of Jaffna that have no link to the main grid. Islands of Nagadeepa, Delft, Analaitivu, and Eluvaithivu are already identified as being isolated from the main grid, with Eluvaithivu island having already implemented a wind and diesel-generating hybrid system. Other major islands rely entirely on diesel generators for power. Table 1 shows the power consumption of the main islands that are not connected to the main grid in the northern province of Sri Lanka.

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Table 1: Main islands in the northern province of Sri Lanka that are not connected to the main grid

Island name	**Nagadeepa**	**Delft**	**Analaitivu**
Current Power Source	Diesel generator	Diesel generator	Diesel generator
Population	3545	4583	1832
No. of Houses	1070	1400	574
Daily Power Consumption	3020kWh	2920kWh	1157kWh
Peak time Power Demand	360A	300A	200A
Generator Capacity	250kVA	250kVA	100kVA
	380kVA	250kVA	100kVA
		330kVA	250kVA

These islands are far from the mainland, so it is expensive to establish undersea cables, and it is hard to build high-voltage overhead distribution lines through deep water. Based on daily power usage and peak time demand, Analaitivu island was chosen to deploy the proposed wind-solar hybrid energy system. Ceylon Electricity Board now powers 574 houses on the island using two 100kVA diesel generators and one 250kVA diesel generator. The island of Analaitivu, which is about 25 kilometers west of the city of Jaffna, is off the coast of the Jaffna peninsula as shown in figure 1. The island, which had a colonial name of Rotterdam, is 4.82 square kilometers in size. (Wikipedia contributors, 2020).

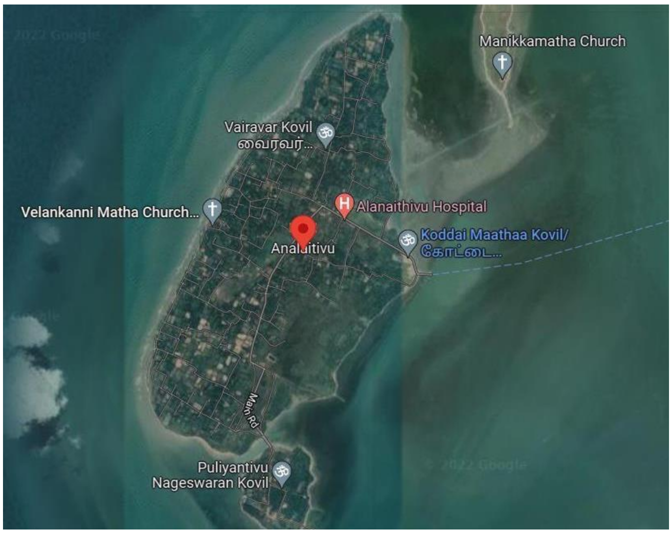

Figure 1: The geographical location of Analaitivu Island

By combining wind and solar energy to create a hybrid power system, the energy demand of the island can be fulfilled. A hybrid power plant needs to be built and optimized to generate electricity at competitive pricing because of the sizable investment cost. Every day, 1157 kWh of power is consumed by the households of Analitivu Island. The monthly usage of the 574 houses ranges from 30000 to 45000 kWh (based on a detailed survey).Each customer has an energy meter attached to their household, and meter readings are taken on a regular basis. However, CEB's operational expenditures for the current diesel power plant are significantly high. The power plant's outdated diesel generators are inefficient leading to diesel wastage since they are never completely loaded. To construct a power system tailored to the island of Analaitivu, precisely forecast of its power requirement is imperative. It should be noted, however, that only 574 individuals are now connected to the system, and the existing electricity supply is only accessible for six and a half hours daily. To ensure efficient and cost-effective use of renewable energy resources, an optimal sizing approach is required. The optimal size approach can assist in ensuring the lowest investment while making maximum use of the system component, allowing the hybrid system to operate at its best in terms of investment and system power reliability.

2.2 Weather data analysis

Fluctuating solar radiation and wind speed parameters have a significant impact on energy generation in renewable energy systems. Figure 2 and Figure 3 show the Monthly average wind speed data and the solar irradiance pattern of Analaitivu island according to the NASA surface meteorology and solar energy database. (Stackhouse, n.d.)

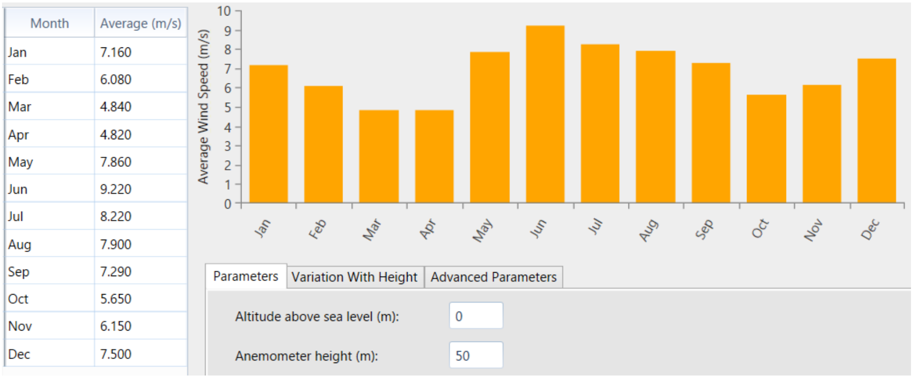

Figure 2: Monthly average wind speed data of Analaitivu island.

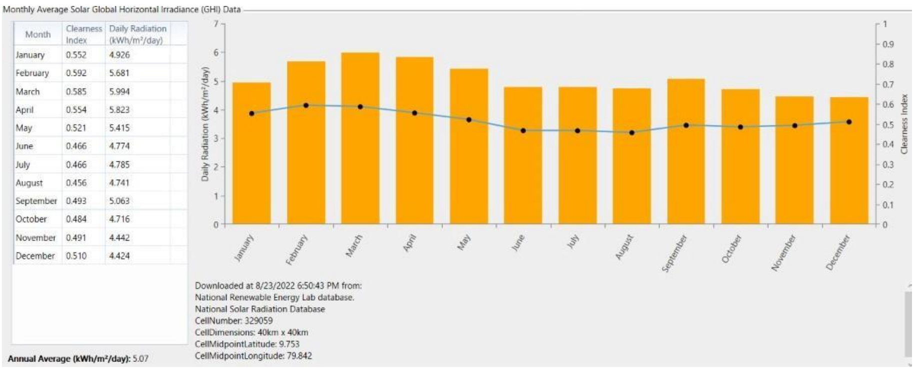

Figure 3: Monthly average solar irradiance pattern of Analaitivu island

The weather on the island is generally similar to the weather in Sri Lanka's northern region. This region mostly experiences rain from October through December. During this season, over 70% of the yearly rainfall occurs. Jaffna peninsula and the islands get notably different yearly rainfall, with 1365mm in Jaffna. 28 °C in December to 33 °C in June being the typical temperatures in the region. (Portal, n.d.). Monthly average temperature data are shown in figure 4.

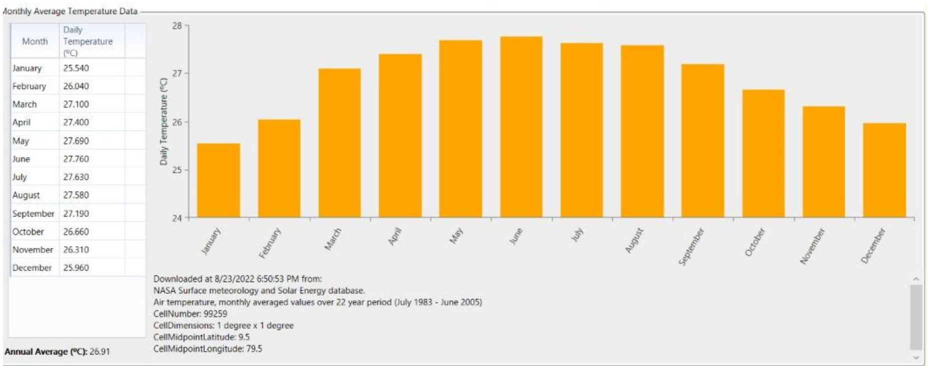

Figure 4: Monthly average temperature data of Analaitivu island

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2.3 Homer optimization

The Hybrid Optimization Model for Electric Renewables (HOMER) is the most commonly used sizing tool created by the National Renewable Energy Laboratory (NREL). This application has been used widely in recent renewable energy system case studies and includes a strong user interface with a full system analysis. HOMER allows users to model PV/wind hybrid systems and conduct sizing and optimization by running the simulation repeatedly and comparing various system setups and component sizes. The electricity produced by renewables, PV and WT, battery charging and discharging, and the computation of the overall net present cost are all based on approximate formulae. After receiving resource data, load data, and power-generating equipment data, as well as the equipment capabilities to be considered, Homer executes a continuous calculation process and ranks the best combinations in priority order based on the discounted lifespan cost. The program offers a selection of locations, and"Analaitivu Island" was selected by providing geographical coordinates. The selected area is located at 09.66912° and 079.776172° geographical coordinates. The data about the site's GHI and temperatures related to the location can be obtained from the resource libraries of Homer software. It is loaded to the database automatically. HOMER software uses imported data to create an approximation of the daily load consumption. Based on the typical electricity usage, the daily load curve is shown in figure 5.

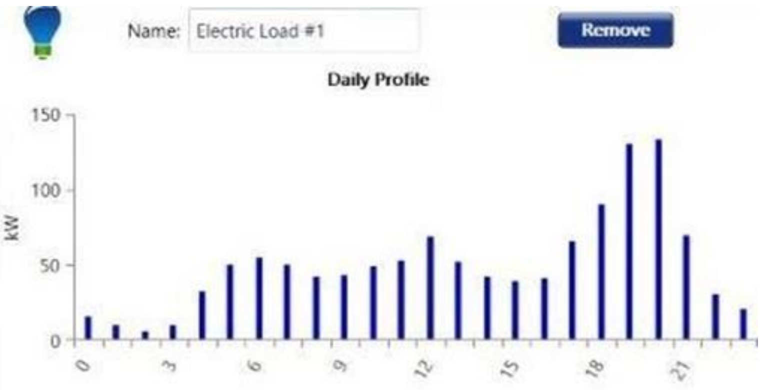


Figure 5: The daily load profile of electricity consumption on Analaitivu island

The daily electrical load curve, which is created to depict the power load as a function of time, is crucial in short-term load forecasting. The plot shows sharp increases in morning, noon, and night, which is noteworthy. Peak demand, which occurs between 6.30 a.m., 12.30 p.m., and 8.30 p.m., is the most critical aspect that must be addressed. The average daily load curve for Sri Lanka has had a clear trend over time, with the load progressively increasing annually.

Table 2: Monthly average electricity consumption on Analaitivu island

Month	**Energy delivery (kWh)**
January	1165.84
February	1123.75
March	1126.97
April	1330.45
May	1020.84
June	1156.97
July	1200.57
August	1157.83
September	1035.67
October	1250.67
November	1160.58
December	1153.96
Average	**1157.008**

Components from HOMER's inventory are available with a set of customizable pricing and capacities. PV cells, wind turbines, batteries, and inverters are the primary components used in this project. Component size, cost, and capacity are further required inputs; however, numerous inputs here enable quantity/capacity optimization. Following a technical review of the components, PV cells, wind generators, and battery cells were selected for installation.

3 SYSTEM DESIGN

3.1 Solar/ Photovoltaic panels

In Homer software, there are several options available when choosing PV panels. The PV catalog lists all the brands available. An estimation of the cost concerning capacity was given by Jinko Eagle PERC60 300W, an electricity provider recognized by Sri Lanka's Sustainable Energy Authority. Sizing optimization was made possible by the addition of multiple capacity options. One of the main factors to consider is the expected lifetime, and according to the Sri Lanka Sustainable Energy Authority, a PV cell is predicted to last 25 years while still performing at an optimal level. Additionally, HOMER sets the panel type to flat, which denotes a zero-degree angle. (ENF Ltd, n.d.).

3.2 Wind turbine

Wind turbine generators are utilized to partially replace the electrical energy produced from solar energy by utilizing the island's significant wind resource. In other words, the solar demand is fairly decreased by retrofitting a wind turbine generator. Although the initial cost of a wind turbine generator is high, the operational cost is extremely low, making the usage of multiple wind turbine generators uneconomical. It was decided to employ two ASW HC wind turbine generators with a capacity of 3.3kW after taking the limitation and the initial investment requirement. into account. (AWS HC Wind Turbines, n.d.)

3.3 Battery bank system

Ion edition LPF 2100Ah Lithium-ion batteries with 100kWh of energy storage each were selected for peak hours. This battery was selected because it has a lifespan of fifteen years and has an initial cost of Rs 710700.00 and Rs 710700.00 replacement cost. The nominal battery capacity is 2100Ah (Homer energy, n.d.). The beginning and minimum states of charge, lifespan, and throughput of this battery are all programmable, but its price is fixed. To fit the battery within the project's concept, the lifetime was set to 15 years.

4 CIRCUIT DIAGRAM

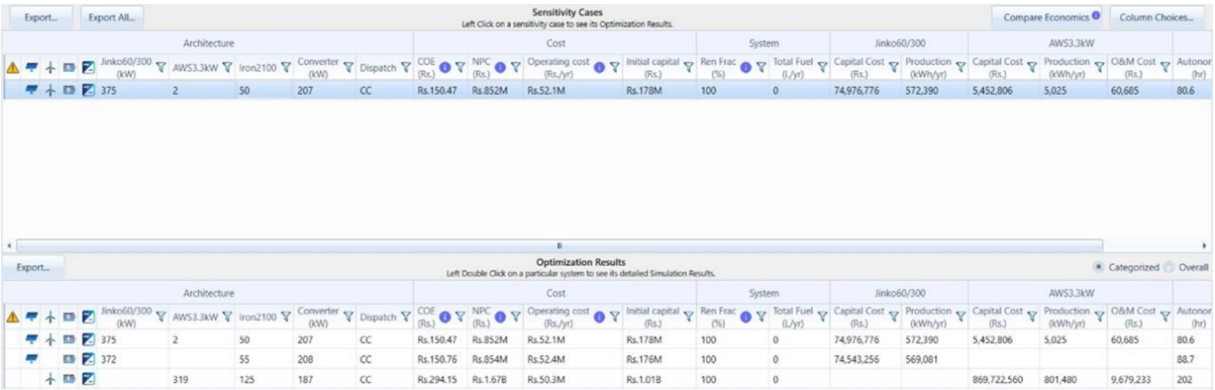
Homer software analyzes the necessary equipment, its sizes, and its usage patterns, and preliminary technical design of the power plant needs to be done to address the precise problems associated with the project's execution. The power flows and fundamental connections between the power plant's components are shown in the schematic design in figure 6.

Figure 6: Schematic design of the system

5 SPECIFICATIONS OF THE PROJECT

Correct equipment size is established after conducting a pre-feasibility study using weather data and the maximum capacity of the system. The dependability and efficiency of an integrated power system are significantly influenced by its unit size. There are several approaches that may be applied to find the most dependable and affordable option. One approach is to use computer modeling and optimization software with inputs for hourly solar radiation, wind speed, and instantaneous efficiency. To discover the optimum solution, another approach uses optimization techniques based on a search methodology. Each use case for a renewable energy system has a unique set of software needs. A pre-feasibility tool is necessary for implementing a renewable energy system since salespeople, promoters, consultants, and planners determine whether a renewable energy system makes sense for a particular application, taking into account both the energy delivered and lifetime cost comparisons of stand-alone systems. Software that calculates the appropriate size for each of the system's numerous components and offers details on system dependability is necessary for designers and installers of renewable energy systems.

The purpose of tool sizing is to specifically lower the life-cycle cost of the system. The end user asks for software that can simulate a renewable energy system's performance under various load and weather scenarios, as well as the capability to contrast predicted outcomes with actual data in order to identify any renewable energy system defects. The inputs supplied to Homer and the assumptions made in giving these inputs have a direct impact on the outputs produced by Homer. As a result, all the technical and economic inputs provided to Homer were either confirmed by obtaining relevant data from the equipment suppliers or were based on logical engineering judgments taking into account the project's background. Figure 7 presents the most reliable technological possibilities according to Net Present Cost (NPC), as determined by Homer software.



Sensitivity Cases

Jinko60/300 (kW)	AWS3.3kW	Iron2100	Converter (kW)	Dispatch	COE (Rs.)	NPC (Rs.)	Operating cost (Rs./yr)	Initial capital (Rs.)	Ren Frac (%)	Total Fuel (L/yr)	Jinko60/300 Capital Cost (Rs.)	Jinko60/300 Production (kWh/yr)	AWS3.3kW Capital Cost (Rs.)	AWS3.3kW Production (kWh/yr)	AWS3.3kW O&M Cost (Rs.)	Autonor (hr)
375	2	50	207	CC	Rs.150.47	Rs.852M	Rs.52.1M	Rs.178M	100	0	74,976,776	572,390	5,452,806	5,025	60,685	80.6

Optimization Results

Jinko60/300 (kW)	AWS3.3kW	Iron2100	Converter (kW)	Dispatch	COE (Rs.)	NPC (Rs.)	Operating cost (Rs./yr)	Initial capital (Rs.)	Ren Frac (%)	Total Fuel (L/yr)	Jinko60/300 Capital Cost (Rs.)	Jinko60/300 Production (kWh/yr)	AWS3.3kW Capital Cost (Rs.)	AWS3.3kW Production (kWh/yr)	AWS3.3kW O&M Cost (Rs.)	Autonor (hr)
375	2	50	207	CC	Rs.150.47	Rs.852M	Rs.52.1M	Rs.178M	100	0	74,976,776	572,390	5,452,806	5,025	60,685	80.6
372		55	208	CC	Rs.150.76	Rs.854M	Rs.52.4M	Rs.176M	100	0	74,543,256	569,081				88.7
	319	125	187	CC	Rs.294.15	Rs.1.67B	Rs.50.3M	Rs.1.01B	100	0			869,722,560	801,480	9,679,233	202

Figure 7: Technology options ranked according to net present cost (NPC)

The winning configuration, as shown in figure 7, is a 375 kW PV system with two 3.3 kW wind generators. As a result, the average power consumption is 1157kWh, hence the plant is designed for 1200kWh. The optimum configuration divided it to have 375 kWh from solar and 6.6 kWh from wind energy. The configuration with a full solar PV system comes in second on the list and is close behind it regarding the reliability of the wind solar hybrid system. As shown in figure 8, the configuration only consists of the wind turbine and can be neglected due to its high NPC value of Rs. 1.67B.

Jinko60/300 (kW)	AWS3.3kW	Iron2100	Converter (kW)	Dispatch	COE (Rs.)	NPC (Rs.)	Operating cost (Rs./yr)	Initial capital (Rs.)
375	2	50	207	CC	Rs.150.47	Rs.852M	Rs.52.1M	Rs.178M
372		55	208	CC	Rs.150.76	Rs.854M	Rs.52.4M	Rs.176M
	319	125	187	CC	Rs.294.15	Rs.1.67B	Rs.50.3M	Rs.1.01B

Figure 8: Cost estimates for the selected power plant configuration

In order to assess the outcome and whether important parameters have deviated from the anticipated values, HOMER is utilized for the sensitivity analysis. Multiple values are entered to do the sensitivity analysis, and then all the variables are optimized. There may be a variation in the outcome once each variable has been optimized, highlighting the influence of the sensitive values. Key characteristics include factors like wind speed and solar hours.

The wind turbine prices considered in the current research are based on those provided by reputable providers in industrialized nations. Accessing affordable wind equipment in the near future appears very likely because of the technological advancements being made in the wind turbine sector in countries like China and India. Therefore, a sensitivity analysis was performed to investigate the effect of component pricing on the successful configuration. This system has a high penetration rate and adaptability to handle any unexpected increases in demand.

6 TECHNO-ECONOMIC ANALYSIS

It is not sufficient to design and select the best configuration for an off-grid solar PV system since the performance of the wind-solar hybrid energy system is also greatly influenced by several financial and performance factors. The following metrics are computed in HOMER software to assess whether building a hybrid system is economically feasible.

6.1 Cost analysis

As is common in any cost-benefit analysis, the objective of the economic analysis is to evaluate the project's economic advantages in comparison to its associated expenses. A financial measurement serves as the benchmark for evaluating costs and benefits. The project's effects are assessed as much as possible in terms of market prices for goods and services. In other words, shadow pricing reflects an effort to shed light on what a good or service costs the economy as a whole.

Table 3 : Cost analysis for the solar PV system

Solar System Capacity - DC (kWp)	**375**	
Panel	**T1 Panel**	
Inverter	**Huawei**	
Exchange Rate	**1US$ = Rs.360**	
	US$	Rs
Total Price including additional	325362	117130320
Features Price per kW	867.632	312347.52
Panels (790)	126400	45504000
Inverters	45084	16230240
Mechanical Structure	18600	6696000
Cables (DC, AC, Earthing)	70800	25488000
Civil & Underground Work	10600	3816000
AC Combiner Box	13600	4896000
Related Insurances	2400	864000
Supplier VAT (@ 15%)	5800	2088000
Others	23000	8280000
Basic System Price	**316284**	**113862240**
Additional Features can be provided at the following prices		
Ladders	1050	378000
Meter Cubicle	2389	860040
Water Line	2250	810000
Inverter Structure	3389	1220040
Additional Features Price	**9078**	**3268080**

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Table 4 : Cost analysis for the wind energy system

Wind System Capacity - DC (kWp)	**6.6**	
Generator	**ASW HC 3.3kW**	
Exchange Rate	**1US$ = Rs.360**	
	US$	**Rs**
Total Price including additional	52860	19029600
Features Price per kW	8009.090909	2883272.727
ASW 3.3KW Wind Turbines x 2	50000	18000000
-Blades		
-Hub		
-Mechanical Structure		
-Bearings		
-Rotor		
-AC Combiner Box		
Cables (DC, AC, Earthing)	560	201600
Civil & Underground Work	600	216000
Basic System Price	**51160**	**18417600**
Additional Features can be provided at the following prices		
Ladders	1700	612000
Additional Features Price	**1700**	**612000**

Table 5: Cost analysis for the battery bank system

Battery Bank Capacity - DC	**5050 kWh**	
Battery Capacity (Ah)		**2100 Ah**
Exchange Rate	**1US$ = Rs 360.00**	
	US$	**Rs**
Total Price including additional	101250.0	36450000.00
features Price per kWh	20.04950495	7217.821782
Battery (50 Units)	98708.3	35535000.00
Mechanical Structure (Rack)	708.3	255000.00
Cables (DC, AC, Earthing)	375.0	135000.00
Civil and Battery bank room Work	763.9	275000.00
Related Insurances	138.9	50000.00
Others	555.6	200000
Basic System Price	**101250.0**	**36450000.00**

6.2 BOQ analysis

The Bill Of Quantities also referred to as a "BOQ" is a document that lists the measured values of the work items that are described by the drawings and specifications. This document is created by the cost consultant, who is typically a quantity surveyor.

Table 6: BOQ analysis for the solar PV system

Item	Description	Quantity
Solar PV Panels	JA/Jinko 475W	790
Inverters	Huawei 100kW with 5 years warranty	3
	Online Monitoring	1
Structure	Aluminum Railing Bars	310
	T Clamp Set	1,400
	Angle Clamp Set	520
	Serrated Angle Bracket	1,500
	Connector Clamp	300
Bus Bar	AC Combiner Box - Venora/EMP	1
Wiring	DC Cables ($6mm^2$)	Multiple
	AC Cables	Multiple
	Grounding Cables	Multiple
Cable Trays	DC Cable Trays	Multiple
	AC Cable Trays	Multiple
Price includes	Design and Engineering Support for the solar system	
	Installation	
	Additional Features as given	
	Testing and Commissioning	
	Transport and Labour	
	Traveling and Accommodation	

Table 7: BOQ analysis for the wind energy system

Item	Description	Quantity
Generator	ASW HC 3.3kW	2
Structure	Aluminum Railing Bars	310
	T Clamp Set	1,400
	Angle Clamp Set	520
	Serrated Angle Bracket	1,500
	Connector Clamp	300
Bus Bar	AC Combiner Box - Venora/EMP	1
Wiring	DC Cables ($6mm^2$)	Multiple
	AC Cables	Multiple
	Grounding Cables	Multiple
Cable Trays	DC Cable Trays	Multiple
	AC Cable Trays	Multiple
Price includes	Design and Engineering Support for the Wind system	
	Installation	

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	Additional Features as given
	Testing and Commissioning
	Transport and Labour
	Traveling and Accommodation

Table 8: BOQ analysis for the battery bank system

Item	**Description**	**Quantity**
Battery	Iron edition LPF 2100Ah	50
Structure	Aluminum Railing Bars	300
	T Clamp Set	
	Angle Clamp Set	
	Serrated Angle Bracket	150
	Connector Clamp	450
Bus Bar	AC Combiner Box - Venora/EMP	2
Wiring	DC Cables ($6mm^2$)	Multiple
	AC Cables	Multiple
	Grounding Cables	Multiple
Cable Trays	DC Cable Trays	Multiple
	AC Cable Trays	Multiple
Price includes	Design and Engineering Support for the Battery system	
	Installation	
	Additional Features as given	
	Testing and Commissioning	
	Transport and Labour	
	Traveling and Accommodation	

6.3 Component brand analysis

When designing the wind-solar hybrid energy system, a brand analysis is performed to determine the most efficient and cost-effective components.

Table 9: Brand analysis for the solar PV system

Description		**Supplier**	**Country of Origin**	**Applicable Warranty Period**
Panels (W)	475Wp Mono	Jinko/JA	China	12 Years - Product Warranty
Inverters (kW)	100kW	Huawei	China	5 Years
Mounting Structure	Structure and Accessories	Lanka Aluminum/ Swisstek	Sri Lanka	10 Years
LV Panel	Combiner Box	EMP/Venora	Sri Lanka	1 Year
Cables	DC Cables (6mm)	Phelps Dodge or Equivalent	Taiwan	1 Year
	AC Cables	Kelani / Sierra or Equivalent	Sri Lanka / India	1 Year
	Earth Cables		Sri Lanka / India	1 Year

Table 10: Brand analysis for the wind energy system

Description		Supplier	Country of Origin	Applicable Warranty Period
Generator	ASW HC 3.3kW	AWS	Australia	5 Years - Product Warranty
Fan Structure	Iron	Melwa	Sri Lanka	25 Years Warranty
Cables	DC Cables (6mm)	Phelps Dodge or Equivalent	Taiwan	1 Year
	AC Cables	Kelani / Sierra or Equivalent	Sri Lanka / India	1 Year
	Earth Cables		Sri Lanka / India	1 Year

Table 11: Brand analysis for the battery bank system

Description		Supplier	Country of Origin	Applicable Warranty Period
Batteries (Ah)	2100Ah,48V	Iron edition LFP	China	10 Years - Product Warranty
Mechanical Structure		Lanka Aluminum / Swisstek	Sri Lanka	10 Years
LV Panel	Combiner Box	EMP/Venora	Sri Lanka	1 Year
Cables	DC Cables (6mm)	Phelps Dodge or Equivalent	Taiwan	1 Year
	AC Cables	Kelani / Sierra or Equivalent	Sri Lanka / India	1 Year
	Earth Cables		Sri Lanka / India	1 Year

6.4 Net present value

An approach for calculating interest is called net present cost, or NPC. Various investment alternatives are adjusted to the year the initial investment cost was made using a specified interest rate. An investment is profitable if the NPC of the future payout exceeds the cost of the initial investment. If the optimization is done correctly, we can calculate the NPC using the HOMER software. The comparison of the NPC values can be seen in Figure 8.

6.5 Payback period

The payback method calculates how long takes to recover the initial investment cost from the invested money. Profitable investments are those where the repayment period is less than the estimated payback period. (SoFi, 2021)

Total price in the implementation of the solar system
= Rs. 117130320.00 (US$ 325362)
Total price in the implementation of the wind system
= Rs. 19029600.00 (US$ 52800)
Total price in the implementation of the battery system
= Rs. 36450000.00 (US$ 101250)
Total project implementation cost
= Rs. (117130320 + 19029600 + 36450000)
= Rs. 172609920.00 (US$ 479,472)
Daily Power generation = 1157kWh
Annual Power consumption = 1157kWh x 365
= 422305kWhYr
Buying Price offering for 1kWh by the government =Rs.34.00

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Return capital for one year = 422305kWhYr x Rs. 34
= Rs. 14358370.00 (US$ 39884.36)
Payback period = Total project implementation cost / Return capital for one year
= 172609920 / 14358370
= 12.022 Years

According to the payback method analysis, it takes 12 years to pay back the initial investment cost.

7 ENVIRONMENTAL IMPACTS

According to table 12, carbon emissions released by the 3 diesel generators are the highest. By designing the proposed wind-solar hybrid system, it uses a green approach to reduce carbon emissions. (Akyuz, 2012). The proposed renewable energy hybrid system is mainly environmentally beneficial, with no carbon emissions.

Table 12: Comparison of emissions between diesel generator power systems and wind-solar power systems

Description	**3 diesel generator-based power systems (100kVA,100kVA,250kVA)**	**Off-grid Wind Solar Hybrid System**
Pollutant	**Emissions (kg/yr)**	**Emissions (kg/yr)**
Carbon Dioxide	1417.284	0
Carbon Monoxide	3496.5	0
Unburned Hydrocarbons	387.45	0
Particulate Matter	263.7	0
Sulfur Dioxide	2844	0
Nitrogen Oxides	31216.5	0

8 CONCLUSION

Investigating whether it would be economically advantageous to build a solar and wind hybrid system on Analaitivu island was one of the objectives of this research. By contrasting the net present value (NPV) and system efficiency, optimization was carried out. Despite the system's economic advantages, the significant investment cost had to be considered as Sri Lanka is a lower-middle-income country, and the investment may not be financially viable for the typical household.

Sri Lanka must move its energy production as part of its efforts to reduce greenhouse gas emissions. In contrast to the energy mix acquired from the grid, solar and wind energy are both sustainable energy sources. A hybrid system is advantageous from a sustainable standpoint since it produces no net carbon emissions and helps the world achieve its sustainable development targets. Therefore, constructing a solar and wind hybrid system is advantageous from an economic and environmental standpoint, leading to a suitable optimization matching the objectives and limitations of the study.

REFERENCES

Akyuz, E. (2012). Researchgate.net. https://www.researchgate.net/publication/264441082_A_case_study_of_hybrid_wind-solar_power_system_for_reduction_of_CO2_emissions

AWS HC Wind Turbines. (n.d.). Aus Wind and Solar. Retrieved December 29, 2022, from https://www.australianwindandsolar.com/aws-wind-turbine-packages

ENF Ltd. (n.d.). ENF Ltd. Enfsolar.com. Retrieved December 29, 2022, from https://www.enfsolar.com/pv/panel-datasheet/crystalline/33723

Homer energy. (n.d.). Homerenergy.com. Retrieved December 29, 2022, from https://www.homerenergy.com/products/pro/docs/latest/storage.html

Portal, C. K. (n.d.). Sri Lanka. Worldbank.org. Retrieved December 29, 2022, from https://climateknowledgeportal.worldbank.org/country/sri-lanka/climate-data-historical
SoFi. (2021, June 25). payback period: Formula. SoFi. https://www.sofi.com/learn/content/how-to-calculate-the-payback-period/
Stackhouse, P. (n.d.). Nasa power. Nasa.gov. Retrieved December 29, 2022, from https://power.larc.nasa.gov/
Wikipedia contributors. (2020, December 10). Analaitivu. Wikipedia, The Free Encyclopedia. https://en.wikipedia.org/w/index.php?title=Analaitivu&oldid=993498547

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