The Energy Management Study of Hybrid Renewable Energy Sources Appropriate to the Load of the Central Sports Stadium in Chaiyaphum Province

Montre Chaleekure, Terapong Boonraksa, Nitikorn Junhuathon, and Boonruang Marungsri*

Abstract— *Renewable energy plays a considerable role in Thailand today since the demand for electricity is increasing both in the household and industrial sectors. It can reduce emissions from the production of electricity from coal, and reduce global warming. Therefore, this paper is a study of the energy management of hybrid renewable energy sources suitable for the load of the central sports stadium in Chaiyaphum province. The Homer Pro is used to analyze the size of a system with integrated renewable energy sources, including solar energy and wind power generation. It also analyzes the economics of the system and analyzes the size and cost of the system with the appropriate battery energy storage system. The simulation results show that grid connections (On-Grid) can save cost more than Off-Grid systems. Due to the Off-Grid system, the cost of the battery is large and expensive. So, with the on-grid system, it is more than worth the investment and can sell the electric power back to the electrical system. However, the Off-Grid system also has advantages for remote areas, and it is useful for systems with small loads. When the price of the battery decreases, Off-Grid systems will play an important role in smart grid systems.*

Keywords— **Energy management, hybrid renewable energy sources, solar energy, wind energy, energy storage system.**

1. INTRODUCTION

Currently, electrical energy has a significant role in the survival of the human. With the demand for more energy, they need a power supply to meet demand. In Thailand, the production of electricity is made from crude oil, coal, and natural gas which cause air pollution. As the amount of fossil fuels decreases, renewable energy is becoming a valuable alternative that can help to supply enough electricity to meet the needs of consumers. The renewable energy sources in Thailand include solar energy, wind energy, wave energy (water), biomass, biogas, etc., which are clean energy and environmentally friendly [1] [2]. Fig. 1 shows the energy consumption by type of energy.

Electric power is considered to be very important. Therefore, we have conducted research on energy management as well as analysis of hybrid renewable energy systems to be applied to each electrical load system. Finding the optimal size of a standalone solar and wind power system, as well as energy storage, is an essential part of energy management. Therefore, the analysis of renewable energy resources thoroughly to reduce the initial costs and operating costs of the system [3]. The energy management strategy for microgrids was developed for use in industrial and small-scale groups, both on the grid and off-grid. This system can help to reduce the cost of electricity and fuel costs, whereby the system can predict the load requirements by finding the appropriate value [4].

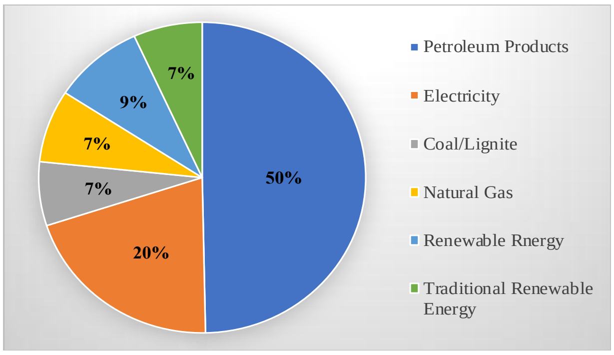

Fig. 1 The energy consumption with the type of energy [2].

The smart grid system gets more attention, which is more intelligent, capable, or more capable of responding to work, using fewer resources and is more efficient, reliable, safe and environmentally friendly. This system has the application of information and communications technology (ICT), sensor systems, data acquisition systems, and automatic control technologies so that the power systems can automatically recognize state information for automated decision making [5]. The energy management methods are presented for hybrid renewable energy systems to supply power to the pumping stations. The combined renewable energy systems include solar cells, fuel cells, and supercapacitors. Using Fuzzy logic control technique for analysis, it can help improve the system performance [6].

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The optimization of the microgrid system using multiple renewable sources is a sophisticated system enhancement. The particular swarm optimization techniques have been applied to analysis [7]. One of the essential factors for the excellent performance of an electrical system is to provide sufficient power to the system. Higher load requirements lead to insecurity and inadequate power supply. The electrical system must be a good correlation between the demand and the available supply to ensure the system stability.In 2011, household energy consumption in Thailand was in third place of total energy consumption. Also, the demand is also rapidly increasing, close to the energy produced [8], [9]. The renewable energy sources in Thailand have increased dramatically since 2006. This is because the Thai government has the policy to support the renewable energy and clean energy, which has a strategic plan for the country, with incentives for subsidies for biomass and solar power [10]. Fig. 2 shows the proportion of fuel used to generate electricity in the system of EGAT in 2018. In the use of renewable energy sources, whether solar or wind energy, it is necessary to examine the environmental impact of producing such energy. It also analyzes and examines the impact on human health, ecological quality, and resource consumption, especially biomass power plants with the most significant environmental impact [11].

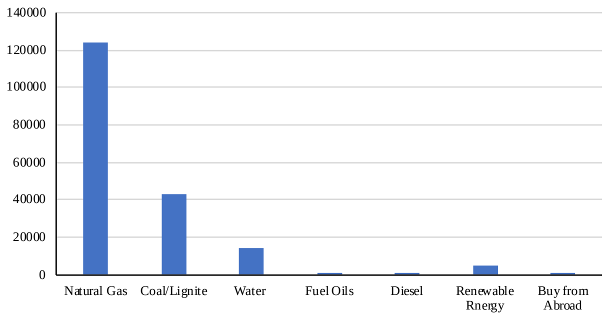


Fig. 2 The proportion of fuel used to generate electricity in the system of EGAT in 2018 [17].

Chaiyaphum province is one of the few areas in Thailand that has the best solar and wind power potential. In order to take advantage of these energies, it is necessary to study the energy management of hybrid renewable energy sources in Chaiyaphum province. Using the HOMER software for analyze to analyzing the renewable energy management to suit the electrical load of this case study. It is the most beneficial use of natural resources, which can reduce the electric charge to a case study area and is a model for other areas.

2. METHODOLOGY

This section describes the theories, techniques for analyzing using the HOMER software, the potential of the area, the case study and the electrical load of the study area.

2.1 HOMER Pro Software

Nowadays, there are several software that has been developed for the design and planning for the production of electricity from renewable energy around the world. HOMER software is a commercially used software developed by the National Renewable Energy Laboratory (NREL), which is a powerful tool for the simulation of hybrid renewable energy sources [12], [13]. The HOMER software can be used to increase the efficiency of renewable energy systems by considering the system's current cost in different configurations and can check the impact of various loads. HOMER software can simulate similar renewable energy technologies and components available. The results are very detailed for analysis and evaluation, considering the possible combinations of technologies and the different sizes of renewable energy sources, and it can work quickly in multiple conditions. The results may be useful in studying, configuring the system, and optimizing the system [14]. So, Homer version 3.11.2 is used for system simulation in this study, which is a form of renewable energy systems that include PV and WG hybrid system being integrated with the battery energy storage system (BESS), with both models, On-Grid and Off-Grid.

Fig. 3 The study area, the central sports stadium in Chaiyaphum Province.

2.2 Study Area

The study area for this research was the central sports stadium in Chaiyaphum Province as shown in Fig. 2. Chaiyaphum Province is located in the northeast of Thailand, while the central sports stadium is under the control of the Chaiyaphum Provincial Administrative Organization. They focus on renewable energy and hybrid renewable energy systems, so this area was selected for this study.

Wind potential in the study area

Wind energy is a natural energy that can be utilized by generating electricity using wind turbines. Wind turbines can change the kinetic energy from the motion of wind into mechanical energy before producing electricity, and the wind power generation is not harmful to the environment. The wind speed data of the study area was measured from the Chaiyaphum Station of Thailand Meteorological Department [15]. A month’s average maximum wind speed is 6.07 m/s, the minimum wind speed 4.49 m/s and the average annual wind speed 5.35 m/s measured at the height of 50 m.

Solar potential in the study area

Solar energy is a clean, pollution-free natural energy that has been used extensively throughout the world. It is a high potential renewable energy that can be used extensively, especially the use of solar energy to produce electricity. It can enhance the stability of the power system and also reduce global warming to one another. Solar cells are electronic devices created to convert solar energy into electricity. Solar power generation has the highest efficiency in daytime operation, which corresponds to peak load applications in the daytime. In Thailand, the highest average sunshine area is in the northeastern part of the country, and the intensity of solar radiation is in the range of 20-24 MJ/m^2/day [16]. In Chaiyaphum province, annual solar radiation is measured, with the average annual average of 6.04 kWh/m^2 in April and the lowest average power of 4.760 kWh/m^2. In the study area, the average solar energy was 5.17 kWh/m^2 and average ambient temperature 20 ^oC.

2.3 Load assessment of the study area

Before selecting any type or size of the renewable energy system, it is necessary to estimate the electrical load carefully. The electrical load data are based on the existing electrical load data of the center sports stadium of the year 2017, which was measured by the installation of a data collection system through the Provincial Electricity Authority. The main electrical load at Chaiyaphum central stadium is the general lighting system, incandescent spotlight, and electric water pumping system. The maximum electric load occurred during May and June, which was calculated by the Homer program as a potential electrical load in the future, averaging 331.6 kWh/day and 120,450 kWh/yr. with a maximum power of 85.64 kW [17]. Fig. 6 and Fig. 7 show the characteristics of the daily electrical load curve and monthly electrical load curve, respectively.

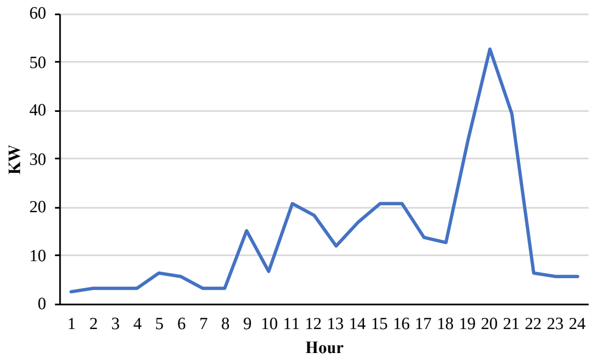


Fig. 6. The daily electrical load curve.

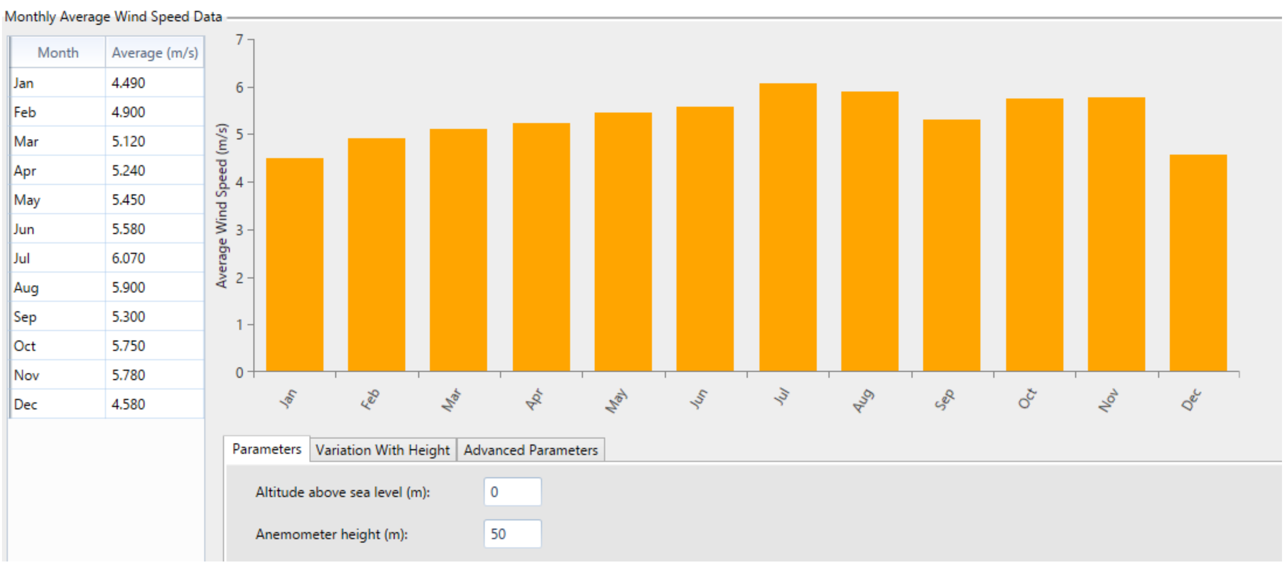


Fig. 4 The data of annual average wind speed for the study area, Chaiyaphum Province.

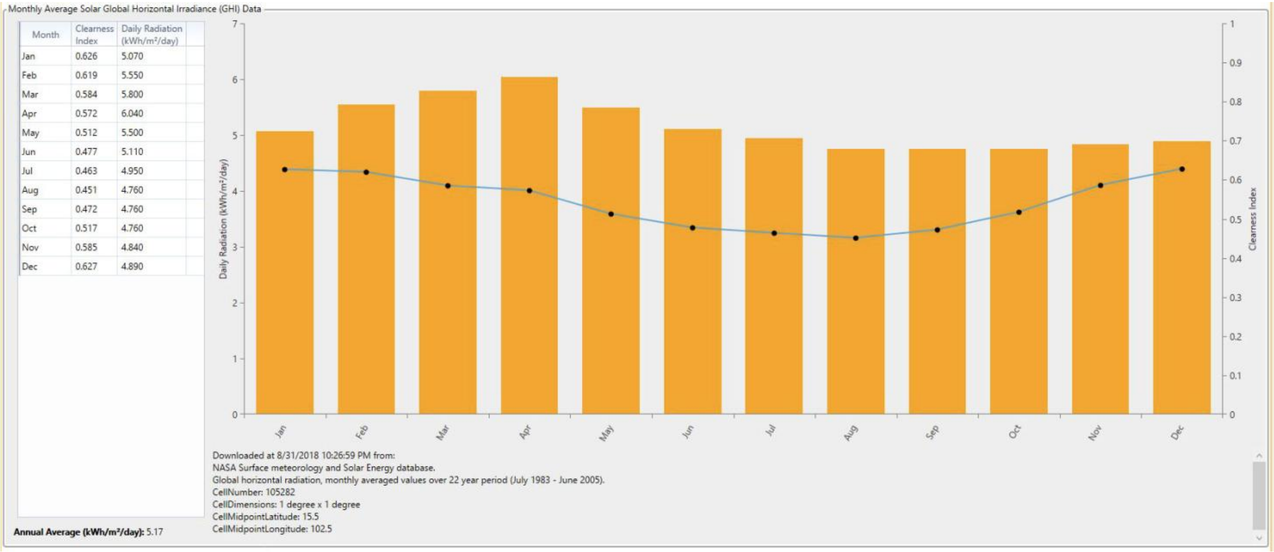


Fig. 5 The data of annual average solar energy for the study area, Chaiyaphum Province.

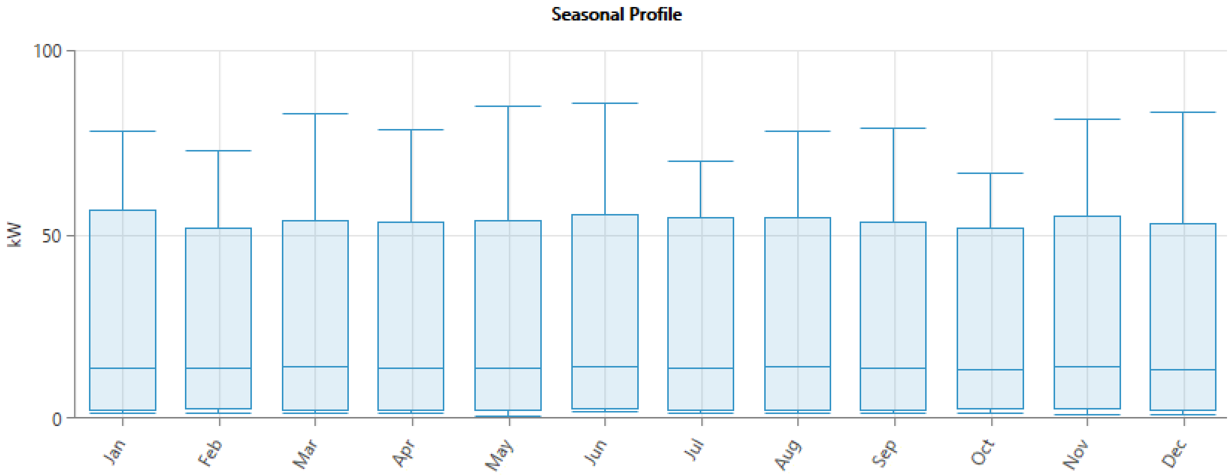


Fig. 7 The monthly electrical load curve.

3. DESIGNING ON-GRID AND OFF-GIRD RENEWABLE SYSTEMS

The subsystem size is determined by the relationship between the electrical energy demands of the electrical load of the Chaiyaphum central stadium with the system type using the HOMER software. In order to find the appropriate subsystem size of the electrical load on the system, choose the system components from the HOMER software for On-Grid and Off-Grid renewable systems. Fig. 8 shows the grid-connected system consisting of a PV array, wind turbine, converter, and grid for a backup system. Fig. 9 shows an Off-Grid system consisting of a PV array, wind turbine, converter, and batteries for a backup system.

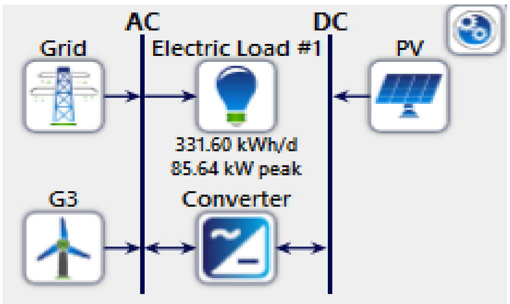


Fig. 8 On-Grid renewable system.

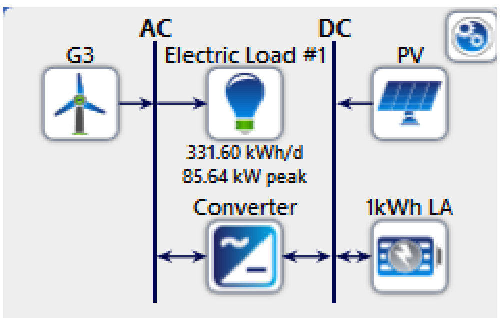


Fig. 9 Off-Grid renewable systems.

After the renewable energy system connects to the program, to give the experimental results which were closest to the actual values, some parameters must be set such as the equipment, installation, and maintenance costs as well as the purchase and the sale rate of electricity. Table 1: shows the cost of equipment in renewable energy systems, which the EPA has determined the purchase price of electricity produced from renewable energy of 6.01 baht/kWh and the electricity is charged with 4.35 baht/kWh [23], [24]. After entering the information into the program, the simulation results are shown in the section below.

4. SIMULATION RESULTS

The simulation results of this study show the size of the subsystem of renewable energy sources and the cost of investment. Fig. 11 shows the results of the On-Grid cost analysis of the renewable energy system. Fig. 14 shows the simulation results of the renewable energy system. A combination of hybrid renewable energy sources combined to produce the electricity and supply to the load was used.

4.1 On-Grid cost analysis of Renewable Energy system

The grid connection system uses grid systems as a backup power source. The monthly average electricity production is shown in Fig. 10. Fig. 12 shows the production and consumption of electricity in the On-Grid system. In the component architecture for PV (kW), optimizing capabilities by selecting 70 kW and WG of 18 kW are combined to meet the maximum power load, and converter 301 kW. The cost will calculate the total cost of the system for 25 years. The COE (cost of energy) is 0.0115 USD, NPC (Net Present Cost) 27,307 USD and initial cost for the system 47,380 USD.

4.2 Off-Grid cost analysis of Renewable Energy system

In the systems that are not connected to the grid, the system uses battery power and has a larger size of renewable energy systems. The average monthly electricity production of this system is shown in Fig.13, and the production and consumption of electricity for the Off-grid system is shown in Fig.15. HOMER selects the solar cell size 135 kW, the wind turbine 42 kW, the battery 962 kWh and the converter 93.2 kW are based on the specified electrical load. The cost will calculate the total system cost for 25 years. So, the COE (cost of energy) is 0.163 USD, NPC (Net Present Cost) 255,589 USD, and the initial cost for the system is 193,932 USD.

Table. 1 Cost of Equipment in Renewable Energy Systems [18-22]

Equipment	Equipment cost (USD)	Installation and Transportation costs (USD)	Maintenance costs/year (USD)
Wind Turbine 3 kW	2,809.85	244.33	24.43
PV array 330 W	128.28	24.43	6.10
Battery 1 kWh	100.9	3.05	1.53
Converter	55.05	1.53	1.53

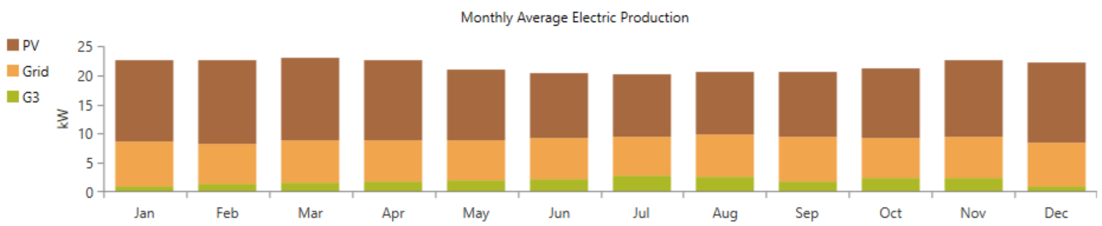
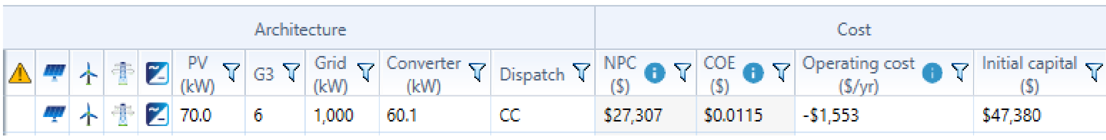


Fig. 10 Monthly electricity production of the On-Grid system.



Architecture									Cost			
					PV (kW)	G3	Grid (kW)	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)
					70.0	6	1,000	60.1	CC	$27,307	$0.0115	-$1,553	$47,380

Fig. 11 The simulation result of On-Grid power system.

Production	kWh/yr	%
Generic flat plate PV	109,892	58.1
Generic 3 kW	16,891	8.92
Grid Purchases	62,470	33.0
Total	189,252	100

Consumption	kWh/yr	%
AC Primary Load	121,034	65.9
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	62,669	34.1
Total	183,703	100

Quantity	kWh/yr	%
Excess Electricity	57.6	0.0304
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	66.0	%
Max. Renew. Penetration	114	%

Fig. 12 Production and consumption of electricity (On-Grid).

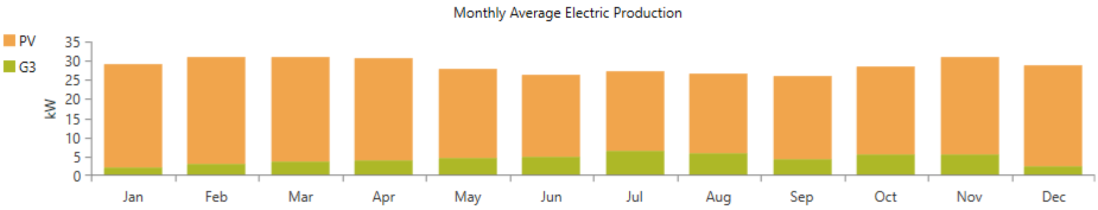


Fig. 13 Monthly electricity production of the Off-Grid system.

Architecture					Cost			
PV (kW)	G3	1kWh LA	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)
135	14	962	93.2	CC	$255,589	$0.163	$4,769	$193,932

Fig. 14 The simulation result of an Off-Grid power system

Production	kWh/yr	%
Generic flat plate PV	211,600	84.3
Generic 3 kW	39,411	15.7
Total	251,012	100

Consumption	kWh/yr	%
AC Primary Load	120,954	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	120,954	100

Quantity	kWh/yr	%
Excess Electricity	110,936	44.2
Unmet Electric Load	79.6	0.0658
Capacity Shortage	120	0.0994

Quantity	Value	Units
Renewable Fraction	100	%
Max. Renew. Penetration	4,538	%

Fig. 15 Production and consumption of electricity (Off-Grid).

Table. 2 Comparative Costs of On-Grid and Off-Grid System

System	PV (USD)	G3 (USD)	Grid (USD)	Battery (USD)	Converter (USD)	Total cost (USD)
On-Grid power system	44,659.37	18,957.99	- 40,841.98	-	4,531.37	27,306.75
Off-Grid power system	85,993.06	44,235.31	-	118,333.95	7,026.55	255,588.86

Table. 3 Electricity Productions

System	Generic flat plate PV	Generic 3 kW	Grid purchases	Total
On-Grid power system	109,892 kWh/yr.	16,891 kWh/yr.	62,470 kWh/yr.	189,252 kWh/yr.
Off-Grid power system	211,600 kWh/yr.	39,411 kWh/yr.	-	251,011 kWh/yr.

Table 2 shows the comparative costs of On-Grid an Off-grid system. On-Grid system had a Total cost of less than Off-Grid system up to 10 times. Due to the On-Grid system, the electricity can be sold back to the grid, which can reduce costs. The Off-Grid system requires more power generation units than the On-Grid system, and with a large battery energy storage system, Off-Grid systems had a total higher cost.

Table 3 shows electricity production; the On-Grid system generates 189,252 kWh/yr of electricity, which is less than the Off-Grid system that can produce 253,011 kWh/yr. Due to the On-Grid systems having the less power generation unit and can purchase the electricity from the power grid (62,470 kWh/yr). It is used as a backup at peak load and during the night. The simulation results of hybrid renewable energy system show the appropriate to the electrical load of the Central Sports Stadium in Chaiyaphum Province.

The On-Grid hybrid renewable energy system is obtained as the best case from this study. The renewable energy sources are wind and solar energy that are 70 kW solar system and a low-speed wind turbine of 18 kW. The size of the solar system is selected more significant than the wind energy because of its lower cost. The Off-Grid systems are so large that they provide enough electricity to load as they are not connected to the electrical system, and the energy is stored in the battery for backup power.

The obtained results can evaluate by comparison with the Frisk's research [25]. The Author in [25] simulated and optimized the hybrid renewable energy system for application on a Cuban farm. The renewable energy sources were PV, wind, biogas, and battery. The annual average electrical load of the system was 264 kWh/day; the peak load was 26.34 kW. As a result, the authors installed a PV system 100 kW and wind 10 kW. The hybrid system (Off-Grid) can produce the electricity 222,374 kWh/yr. The Total cost of the system 419,000 USD. Compared to the study results, the size of the installed system and the amount of electricity produced were comparable. The price of the system is high, probably due to the cost of each component is not equal, some components may be expensive. For comparison, this results show the installation size of the hybrid system that tends to go in the same way.

5. CONCLUSION

The energy management of renewable energy sources is essential in making the most of the energy conversion and use of natural energy. In the study area, the electric load of the center sports stadium in Chaiyaphum Provincial, using the 1-year electricity data from the Provincial Electricity Authority was used. It is used as the basis for analyzing subsystems of integrated renewable energy systems and analyzing system interactions between solar cells, wind turbines, battery, and other devices, both On-Grid and Off-Grid system.

The grid connection system uses grid systems as a backup power source. This article analyzes the cost of On-Grid and Off-Grid hybrid renewable energy systems at the center sports stadium in Chaiyaphum Provincial. The simulation results show that grid connections (On-Grid) can save cost more than Off-Grid systems. Due to the Off-Grid system, the cost of the battery is large and expensive. So, with the On-Grid system, it is more than worth the investment and can sell the electric power back to the electrical system. However, the Off-grid system also has advantages for remote areas, and it is useful for systems with small loads. When the price of the battery decreases, Off-Grid systems will play an essential role in the smart grid systems.

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