International Journal of Scientific Multidisciplinary Research (IJSMR)
Vol.2, No.9, 2024: 1289-1308

Hybrid Solar Cell and Wind Turbine Technology with Android-Based Control System for Electricity Needs of Shrimp Farmers in Pangkep Regency

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A R T I C L E I N F O

Keywords: Hybrid Solar Cell, Wind Turbine, Android, Shrimp, Farmer

Received : 7 July
Revised : 9 August
Accepted: 17 September

A B S T R A C T

The implementation of hybrid solar cell and wind turbine technology can meet the electricity supply needs of shrimp farming partners by converting solar and wind energy into electrical energy. This reduces production costs related to electricity expenditures, as a significant portion is supplied by the hybrid solar cell and wind turbine technology. The sustainable design resulting from the application of hybrid solar cell and wind turbine technology enables the Tumampua shrimp farming group to become self-reliant and resilient in their electricity needs. This approach has the potential for mass application by other shrimp farming groups in Boriappaka Village, Pangkep Regency, fostering energy-independent communities and contributing to environmental protection and conservation

DOI: https://doi.org/10.55927/ijsmr.v2i9.11218
ISSN-E: 2986-5042
https://journal.formosapublisher.org/index.php/ijsmr

INTRODUCTION

Boriappaka Village is one of the eight villages/urban districts in Bungoro Subdistrict, Pangkep Regency, South Sulawesi Province, Indonesia. According to the Pangkep Regency Central Statistics Agency (2018), Bungoro Subdistrict covers an area of 90.12 km^2. The population of Boriappaka Village is 3,463, consisting of 2,286 men and 1,177 women (SIGAPangkep, 2019). The main occupations in Boriappaka Village are farming and shrimp farming, while some residents are employed as civil servants and entrepreneurs. The demographic condition is predominantly coastal, with the remaining areas being land, which is utilized by most residents, making shrimp farming a primary occupation.

Based on the South Sulawesi Province's leading commodity data from 2014-2016, shrimp production in Pangkep has been increasing annually across various subdistricts, including Bungoro Subdistrict. The increase in shrimp production in Pangkep Regency is partly due to the output from traditional shrimp farms. However, one of the challenges faced by traditional shrimp farmers is the inadequate quality of shrimp ponds, which is caused by insufficient access to and fulfillment of electricity needs. (Ali et al., 2022).

The availability of electricity at the shrimp ponds allows for the implementation of various technologies to improve pond quality, which in turn affects the increase in shrimp production. For example, installing aerators can enhance oxygen levels in the pond, maintaining shrimp productivity. Additionally, providing lighting systems around the pond facilitates feeding shrimp at night, prevents theft, and deters animals such as cattle, goats, and dogs. Furthermore, many other technologies can be applied with the availability of electricity at these shrimp ponds. (Nugraha et al., 2020).

The issue of unmet electricity access and needs poses a significant challenge for traditional shrimp farms. To enhance production, one of our partners, who has chosen shrimp farming as their primary occupation, is the Tumampua Shrimp Farming Group, led by Ince Mansyur. This group operates a traditional shrimp farm located at Jl. Bontorannu, Boriappaka Village, Bungoro Subdistrict, Pangkep Regency. The main challenge faced by this shrimp farming partner is the lack of electricity access at their farm, which results in lower shrimp production compared to other shrimp farmers. (Subair & Haris, 2019).

The difficulty in accessing electricity for the farm managed by our partner hampers the improvement of pond management quality. As a result, shrimp production is constrained. Given the environmental potential around the shrimp ponds, there are several potential energy sources that could be utilized, such as alternative power generation methods. These alternatives could provide the shrimp farmers with access to environmentally friendly energy sources, which would support the enhancement of pond management and increase shrimp production. (Bawono, 2019).

The availability of energy sources can significantly impact the increase in shrimp production.

Figure 1. Traditional Shrimp Pond of the Partner

Based on the observations, through the Student Creativity Program (PKM-PI) activities, we intend to provide environmentally friendly power generation technology that offers an unlimited energy source and can reduce operational costs. We aim to ensure that electricity needs are met for the shrimp ponds managed by our partner by implementing technology that utilizes renewable energy sources, such as solar and wind energy. Specifically, we propose using Hybrid Solar Cell and Wind Turbine Technology with an Android-Based Control System to meet the electricity needs of shrimp farmers in Pangkep Regency. The inclusion of an Android-based control system will facilitate easier use of this technology for the shrimp farmers.

LITERATURE REVIEW

Hybrid Solar Cell and Wind Turbine Technology

Hybrid technology is a system that combines two or more different energy sources. An example of a hybrid system commonly encountered today is the combination of solar cells, or photovoltaic panels, with electricity from the national power grid (PLN). This combination of energy sources is typically referred to as a Hybrid Solar Power System (PLTS) designed to meet electricity needs. (Nuryanto, 2022).

Figure 2. Hybrid Solar Cell and Wind Turbine

Hybrid solar cell and wind turbine technology combines solar energy captured by solar panels, which is converted into electrical energy, with wind energy captured by wind turbines, which is also converted into electrical energy. This integration of energy sources allows for the elimination of dependence on the national power grid (PLN). However, this system requires a large battery capacity to maximize energy storage. (Rauf, 2023).

Solar and Wind Energy Sources

According to (Qomaria & Sudarti, 2021) solar energy harnesses sunlight and heat from the sun as a renewable energy source. However, utilizing this energy requires a range of technologies to convert sunlight and heat into usable power, one of which is Solar Cell technology (solar panels).

The International Energy Agency (IEA) states that "advances in affordable, unlimited, and clean solar energy technology will provide benefits." By utilizing solar energy, we can reduce dependence on fossil fuels, enhance sustainability, decrease air pollution, lower the risk of climate change-related disasters, and stabilize current fossil fuel prices. (Wijayanti, 2023). According to various studies, the solar energy received by the Earth's surface amounts to 3 x 10^{24} joules per year, which is equivalent to 10,000 times the current global energy consumption. Indonesia, being located in the tropical region, has a significant solar energy potential, averaging around 4.8 kWh/m² per day, or approximately 112,000 GWp.

Wind energy is a limitless potential energy source that can be harnessed for electricity generation using technologies such as wind turbines. According to wind energy potential analysis and mapping conducted by the Ministry of Energy and Mineral Resources of the Republic of Indonesia, the country has a potential of 978 MW of wind power. This data highlights the significant renewable energy potential available for use as a new, environmentally friendly electricity generation source (Santoso, 2024).

Geographical and Climate Conditions of Pangkep Regency

Pangkep Regency and its islands are located in the western part of South Sulawesi Province, with the capital city of Pangkep. Geographically, Pangkep Regency and its islands are situated at 11°00' East longitude and 0°40' - 08°00' South latitude. Administratively, the total area of Pangkep Regency and its islands is 12,362.73 km², including 11,464.44 km² of marine area and 898.29 km² of land, with a coastline length of 250 km extending to the east. (PangkepKab, 2019)

According to the Köppen climate classification, Pangkep Regency has a tropical monsoon climate (Am), characterized by two distinct seasons caused by the movement of monsoon winds: the rainy season and the dry season. This is due to the influence of the west and east monsoon winds. The dry season is relatively short, lasting from June to October, with average monthly rainfall below 120 mm. In contrast, the rainy season is considerably longer, from November to May, with average monthly rainfall exceeding 200 mm. The wettest month is January, with rainfall exceeding 560 mm. (Susilo, 2021).

Arduino

Arduino is an open-source electronic kit or circuit board that contains a key component: a microcontroller chip from Atmel, specifically an AVR chip. (Ridarmin et al., 2019). Arduino is described as a platform for physical computing that is open-source. The term "platform" here is appropriate as it signifies a tool that encompasses development, programming languages, and an Integrated Development Environment (IDE). Arduino serves as a development tool, combining programming languages and an IDE to facilitate the creation and interaction of electronic projects.


Figure 3. Arduino

An IDE (Integrated Development Environment) is software that facilitates writing programs, converting the code into binary format readable by machines, and uploading it into the microcontroller's memory. Based on (Mubaroq, 2019) The components on the Arduino board use an 8-bit microcontroller with the Atmega brand, manufactured by Atmel. There are various types of Arduino boards based on their specifications, such as Arduino Serial, Arduino Fio, and different Atmega-based Arduino models like the Atmega328. The more advanced Arduino Mega 2560 uses the Atmega 2560 microcontroller."

Android

Based on (Gunantoro, 2019) Android is an operating system for mobile devices based on Linux, encompassing the operating system, middleware, and applications. It provides an open-source platform for developers to create their applications. Android is a Linux-based operating system (OS) designed for mobile devices like smartphones and tablets, similar to how Symbian is used in certain mobile phones. To put it simply, Android is to smartphones and tablets what Microsoft Windows is to computers and laptops—Android is the "Windows" of mobile devices, while smartphones and other mobile devices are the equivalent of the computer unit (Lestari, 2017).

The integration of an open-source distribution system allows for the development of various applications that cater to users' needs, such as games, chatting, and more. This is one of the key factors that make Android smartphones more affordable compared to similar gadgets (Setiawan et al., 2019).

METHODOLOGY

This research is a descriptive study that employs descriptive analysis techniques by observing and recording experimental results directly, then presenting the data and drawing conclusions from the research conducted. Additionally, it aims to evaluate the performance of hybrid solar cell and wind turbine technology under static load conditions in terms of power output and efficiency.

The research location is in Kelurahan Boriappaka, Kecamatan Bungoro, Kabupaten Pangkep. The outcome of this stage is a descriptive overview of the hybrid solar cell and wind turbine model with an Android-based system that meets the required electricity needs.

Data collection and literature review involve gathering information from various sources to support the program's implementation. This is based on references that have undergone research and testing phases, such as scientific articles, academic books, and other relevant sources.

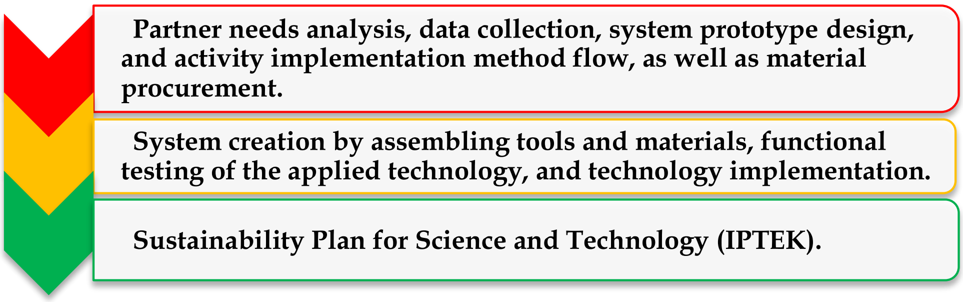

Figure 4. Activity Implementation Method Flow Diagram

RESULTS AND DISCUSSION

Results of Power and Efficiency Measurements for Solar Power Generation

Power Calculation Analysis *Output Photovoltaic*

Table 1. Results of Photovoltaic Power Measurements

Day-1					
Time (Wita)	Panel Area (m^2)	Radiation (W/m^2)	Voltage (V)	Current (A)	P_{out} (W)
07.00	1,306	453,46	14,05	3,00	42,15
08.00	1,306	529,0	14,15	3,58	50,66
09.00	1,306	707,2	14,74	5,00	73,70
10.00	1,306	806,6	15,42	7,40	114,11
11.00	1,306	891,1	15,87	8,09	128,39
Waktu (Wita)	Luas Panel (m^2)	Radiasi (W/m^2)	Tegangan (V)	Arus (A)	P_{out} (W)
12.00	1,306	1.058,6	16,68	9,68	161,46
13.00	1,306	1.011,2	16,23	9,44	153,21
14.00	1,306	796,3	15,33	6,87	105,32
15.00	1,306	397,4	13,83	2,48	34,30
16.00	1,306	374,1	13,52	2,32	31,37
17.00	1,306	275,3	13,19	1,49	19,65
Output Power		*Average (W)*			83,12
		Minimum (W)			`19,65
		Maximum (W)			161,46

In Table 1, the output power measurements were obtained through voltage and current readings of a 200 W polycrystalline solar cell on May 31, 2023. The minimum output power recorded was 19.65 W, the maximum was 161.46 W, and the average output power was 83.12 W.

Table 2. Output Power of 200 W Polycrystalline Solar Cell by Hour

Time (Wita)	*Output Power*							Avarage (W)
	P_{out} (W) H-1	P_{out} (W) H-2	P_{out} (W) H-3	P_{out} (W) H-4	P_{out} (W) H-5	P_{out} (W) H-6	P_{out} (W) H-7	
07.00	42,15	26,2	26,1	36,9	45,88	37,4	28,1	34,68
08.00	50,66	34,3	41	53,2	83,51	47,9	38,1	49,81
09.00	73,70	34,8	47,6	72,4	67,82	63,1	44,9	57,76
10.00	114,11	129,5	154,7	148,9	161,39	152,9	143,9	143,63
11.00	128,39	143,9	173	177,8	174,7	170,1	159,9	161,11
12.00	161,46	165,5	194,2	191,5	190,65	188	181,7	181,86
13.00	153,21	189,4	180,4	158,6	186,53	166,1	185,5	174,25
14.00	105,32	117,9	127,7	151,7	113,17	125,9	117,9	122,80
15.00	34,30	34	43,8	70,9	42,72	58,3	57,9	48,85
16.00	31,37	20,3	26,5	46,9	29	44,4	40,5	34,14
17.00	19,65	16,1	23,2	26,7	12,61	26,6	20,1	20,71
Output Power				*Average (W)*				93,60
				Minimum (W)				20,71
				Maximum (W)				181, 86

In Table 2, the output power measurements were taken hourly through voltage and current readings of a 200 W polycrystalline solar cell from May 31 to June 6, 2023. The minimum average output power recorded was 20.71 W at 5:00 PM WITA, the maximum was 181.86 W at 12:00 PM WITA, and the average output power was 93.60 W.

Table 3. Average Photovoltaic Power Over 7 Days

Time	*Minimum* (W)	*Maximum* (W)	*Average* (W)
31 Mei 2023	19,65	161,46	83,12
1 Juni 2023	16,1	189,4	82,9
2 Juni 2023	23,3	194,3	94,38
3 Juni 2023	26,7	191,5	103,22
4 Juni 2023	12,61	190,65	100,72
5 Juni 2023	26,6	188	98,24
6 Juni 2023	20,1	185,5	92,59
Output Power	*Minimum* (W)	*Maximum* (W)	*Average* (W)
	12,61	194,3	84,86

In Table 3, the output power measurements were obtained through periodic voltage and current readings of a 200 W polycrystalline solar cell from May 31 to June 6. The minimum output power recorded was 12.61 W on Day 5 (June 4, 2023) at 5:00 PM WITA, the maximum was 194.2 W on Day 3 (June 2, 2023) at 12:00 PM WITA, and the average output power was 84.86 W.

Photovoltaic Efficiency Calculation Analysis

Table 4. Results of Photovoltaic Efficiency Measurements

Time (Wita)	Radiation (Lux)	Radiation (W/m^2)	P_{in} (W)	P_{out} (W)	efficiency (%)
07.00	5740 x10	453,46	592,2	42,15	7,12
08.00	6696 x10	529,0	690,9	50,66	7,33
09.00	8952 x10	707,2	923,6	73,70	7,98
10.00	1021 x 100	806,6	1.053,4	114,11	10,83
11.00	1128 x 100	891,1	1.163,8	128,39	11,03
12.00	1340 x 100	1.058,6	1.382,5	161,46	11,68
13.00	1280 x 100	1.011,2	1.320,6	153,21	11,60
14.00	1008 x 100	796,3	1.040,0	105,32	10,13
15.00	5031 x 10	397,4	519,1	34,30	6,61
16.00	4736 x 10	374,1	488,6	31,37	6,42
17.00	3485 x 10	275,3	359,6	19,65	5,46
efficiency			*Average* (%)		8,74
			Minimum (%)		5,46
			Maximum (%)		11,68

In Table 4, the efficiency measurements are obtained through Pin, derived from solar radiation and the surface area of the solar cell, with Pout (output power of the solar cell) produced by a 200 W polycrystalline solar cell on May 31, 2023. The minimum efficiency recorded was 5.46%, the maximum was 11.68%, and the average efficiency was 8.74%.

Tabel 5. Daily Average Photovoltaic Efficiency

Time (Wita)	efficiency							*Average*
	n (%) H-1	*n* (%) H-2	*n* (%) H-3	*n* (%) H-4	*n* (%) H-5	*n* (%) H-6	*n* (%) H-7	
07.00	7,12	6,02	6,01	6,86	7,1	6,87	6,15	6,59
08.00	7,33	6,63	7,06	7,55	9,2	7,15	6,9	7,40
09.00	7,98	6,64	7,15	8,6	8,4	8,05	7,1	7,70
10.00	10,83	11,07	11,35	11,23	11,5	11,31	11,2	11,21
11.00	11,03	11,15	11,67	11,75	11,7	11,63	11,5	11,49
12.00	11,68	11,55	12,22	12,07	12	11,95	11,8	11,90
13.00	11,60	11,99	11,79	11,43	11,9	11,59	11,9	11,74
14.00	10,13	10,87	10,99	11,27	10,9	10,95	10,87	10,85
15.00	6,61	6,64	7,09	8,55	7,1	7,75	7,7	7,35
16.00	6,42	5,52	6,03	7,13	6,3	7,1	7,1	6,51
17.00	5,46	5,11	5,8	6,05	4,6	6,04	5,1	5,45
efficiency				*Average* (%)				8,93
				Minimum (%)				5,45
				Maximum (%)				11,90

In Table 5, the efficiency measurements obtained through hourly readings of Pin and Pout of a 200 W polycrystalline solar cell from May 31 to June 6 show that the minimum average efficiency was 5.45% at 5:00 PM WITA, the maximum was 11.90% at 12:00 PM WITA, and the average efficiency was 8.93%.

Table 6. Average Efficiency of Photovoltaic Cells Over 7 Days

date	*Minimum* (%)	*Maximum* (%)	*Average* (%)
31 Mei 2023	5,46	11,68	8,74
1 Juni 2023	5,11	11,99	8,47
2 Juni 2023	5,8	12,22	8,83
3 Juni 2023	6,05	12,07	9,31
4 Juni 2023	4,65	12	9,15
5 Juni 2023	6,04	11,95	9,12
6 Juni 2023	5,1	11,90	8,84
Efficiency	*Minimum* (%)	*Maximum* (%)	*Average* (%)
	4,65	12,22	8,92

In Table 6, the efficiency measurements obtained through periodic readings of Pin and Pout of a 200 W polycrystalline solar cell from May 31 to June 6 show that the minimum efficiency on day 5 (June 4, 2023) was 4.65% at 5:00 PM WITA, the maximum on day 3 (June 2, 2023) was 12.22% at 12:00 PM WITA, and the average efficiency was 8.92%.

Power and Efficiency Measurement Results of Wind Turbine Power Plant

Analysis of Wind Turbine Output Power Calculation

Table 7. Measurement Results of a 400 W Horizontal Wind Turbine

Date 1 (31 May 2023)						
Time (Wita)	Air Density (Kg/m^3)	Motor Swept Diameter (m^2)	Wind Speed (m/s)	Voltage (V)	Current (A)	P_{out} (W)
07.00	1,225	1,326	3,4	4,4	1,78	7,82
08.00	1,225	1,326	3,1	3,5	1,59	5,56
09.00	1,225	1,326	5,6	11	4,60	50,63
10.00	1,225	1,326	7,2	15,8	8,69	137,32
11.00	1,225	1,326	6,8	14,6	7,33	107,00
12.00	1,225	1,326	4,2	6,8	2,52	17,15
13.00	1,225	1,326	4,6	8	3,01	24,11
14.00	1,225	1,326	5,2	9,8	3,90	38,26
15.00	1,225	1,326	7,8	17,6	11,89	209,28
16.00	1,225	1,326	6,4	13,4	6,28	84,10
17.00	1,225	1,326	5,6	11	4,60	50,63
Output Power			*Average* (%)			66,53
			Minimum (%)			5,56
			Maximum (%)			209,28

In Table 7, the power output measurements obtained through voltage and current readings of a 400 W wind turbine on May 31, 2023, show a minimum power output of 5.56 W, a maximum of 209.28 W, and an average power output of 66.53 W

Table 8. Average Power of a 400 W Wind Turbine Per Hour

Time (Wita)	*Output Power*							*Average*
	P_{out} (W) H-1	P_{out} (W) H-2	P_{out} (W) H-3	P_{out} (W) H-4	P_{out} (W) H-5	P_{out} (W) H-6	P_{out} (W) H-7	
07.00	7,82	17,15	10,7	132,78	0	18,73	47,29	33,50
08.00	5,56	15,39	14,29	89,22	16,85	28,29	74,52	34,87
09.00	50,63	107	182,9	28,29	20,41	22,2	28,29	62,82
10.00	137,32	38,26	137,32	79,2	57,84	26,14	137,32	87,63
11.00	107	30,58	47,29	47,29	127,32	17,15	209,28	83,70
12.00	17,15	8,71	26,14	6,25	38,26	14,29	20,41	18,74
13.00	24,11	26,14	35,55	10,7	20,41	18,73	6,12	20,25
14.00	38,26	7,82	18,73	38,26	54,15	30,58	26,14	30,56
15.00	209,28	35,02	158,96	107	89,22	100,15	84,1	111,96
16.00	84,1	84,1	223,44	61,72	74,52	137,32	249,48	130,67
17.00	50,63	54,15	35,55	249,48	65,79	44,12	112,59	87,47
Output Power			*Average* (W)					63,83
			Minimum (W)					18,74
			Maximum (W)					130,67

In Table 8, the power output measurements obtained through hourly voltage and current readings of a 400 W wind turbine from May 31 to June 6 show a minimum average power output of 18.74 W at 12:00 WITA, a maximum of 130.67 W at 16:00 WITA, and an average power output of 63.83 W.

Table 9. Average Power of 400 W Wind Turbine for 7 Days

Tanggal	*Minimum* (W)	*Maximum* (W)	*Average* (W)
31 Mei 2023	5,56	209,28	66,53
1 Juni 2023	7,82	107	38,57
2 Juni 2023	10,7	223,44	80,98
3 Juni 2023	6,25	249,48	77,29
4 Juni 2023	0	127,32	51,34
5 Juni 2023	14,29	137,32	41,60
6 Juni 2023	6,12	249,48	90,50
Daya *Output*	*Minimum* (W)	*Maximum* (W)	*Average* (W)
	0	249,48	63,83

In Table 9, the power output measurements obtained through periodic voltage and current readings of a 400 W wind turbine from May 31 to June 6 show a minimum power output of 0 W on the 5th day (June 4, 2023) at 07:00 WITA, a maximum of 249.48 W on the 4th and 7th days (June 3 & 6, 2023) at 17:00 and 16:00 WITA, and an average power output of 63.83 W.

Analysis of Wind Turbine Efficiency Calculation

Table 10. Measurement Results of Efficiency for a 400 W Horizontal Wind Turbine

Time (Wita)	Wind Speed (m/s)	RPM	P_{in} (W)	P_{out} (W)	efficiency (%)
07.00	3,4	253,85	31,92	7,82	24,5
08.00	3,1	199,46	24,20	5,56	23,0
09.00	5,6	652,77	142,63	50,63	35,5
10.00	7,2	942,91	303,14	137,32	45,3
11.00	6,8	870,36	255,37	107,00	41,9
12.00	4,2	398,92	60,17	17,15	28,5
13.00	4,6	471,44	79,05	24,11	30,5
Time (Wita)	Wind Speed (m/s)	RPM	P_{in} (W)	P_{out} (W)	efficiency (%)
14.00	5,2	580,25	114,20	38,26	33,5
15.00	7,8	1051,69	385,42	209,28	54,3
16.00	6,4	797,84	212,91	84,10	39,5
17.00	5,6	652,77	142,63	50,63	35,5
efficiency		*Average* (%)			35,63
		Minimum (%)			23,0
		Maximum (%)			54,3

In Table 10, the efficiency measurement obtained through Pin is derived from the mass of the air, wind speed, and rotor sweep diameter, with Pout (the output power of the wind turbine) being the power produced by the 400 W wind turbine on May 31, 2023. The minimum efficiency is 23%, the maximum efficiency is 54.3%, and the average efficiency is 35.63%.

Table 11. Average Efficiency of a 400 W Horizontal Wind Turbine Per Hour

Time (Wita)	Efisiensi							*Average*
	n (%) H-1	n (%) H-2	n (%) H-3	n (%) H-4	n (%) H-5	n (%) H-6	n (%) H-7	
07.00	24,5	28,5	26	43,8	0	29	35	26,69
08.00	23	27,5	27,5	40	28	31,5	38,5	30,86
09.00	35,5	41,9	51,3	31,5	29,5	30	31,5	35,89
10.00	45,3	33,5	45,3	39	36,5	31	45,3	39,41
11.00	41,9	32	35	35	43,8	28,5	54,3	38,64
12.00	28,5	25	31	23,5	33,5	27,5	29,5	28,36
13.00	30,5	31	33	26	29,5	29	23	28,86
14.00	33,5	24,5	29	33,5	36	32	31	31,36
15.00	54,3	10,2	48,3	41,9	40	41	39,5	39,31
16.00	39,5	39,5	55,8	37	38,5	45,3	57,8	44,77
17.00	35,5	36	33	57,8	37,5	34,5	42,2	39,50
efficiency				*Average* (%)				34,87
				Minimum (%)				26,69
				Maximum (%)				44,77

In Table 11, the efficiency measurements obtained from hourly measurements of Pin and Pout generated by the 400 W wind turbine from May 31 to June 6 show an average minimum efficiency of 26.69% at 7:00 AM WITA, a maximum efficiency of 44.77% at 4:00 PM WITA, and an average efficiency of 34.87%.

Table 12. Average Efficiency of a 400 W Horizontal Wind Turbine Over 7 Days.

Date	*Minimum* (%)	*Maximum* (%)	*Average* (%)
31 Mei 2023	23	54,3	35,63
1 Juni 2023	10,2	41,9	29,96
2 Juni 2023	26	55,8	37,74
3 Juni 2023	23,5	57,8	37,18
4 Juni 2023	0	43,8	32,07
5 Juni 2023	27,5	45,3	32,66
6 Juni 2023	23	57,8	38,17
efficiency	*Minimum* (%)	*Maximum* (%)	*Average* (%)
	0	57,8	34,77

In Table 12 and Figure 10, the efficiency measurements were obtained through periodic monitoring of the Pin and Pout of a 400 W wind turbine from May 31 to June 6. The minimum efficiency occurred on the 5th day (June 4, 2023) at 7:00 AM WITA, reaching 0%, while the maximum efficiency was recorded on the 3rd and 7th days (June 3 & 6, 2023) at 5:00 PM and 4:00 PM WITA, respectively, with a peak of 57.8%. The average efficiency over the period was 34.77%.

Measurement Results of Power and Efficiency of Hybrid Power Generation Analysis of the Output Power Calculation for Hybrid Technology

Table 13. Power Measurement Results of the PLTH

Hari 1 (31 Juni 2023)					
Time (Wita)	P_{in} *Solar Cell* (W)	P_{in} *Wind Turbine* (W)	Hybrid Voltage (V)	Hybrid Current (A)	P_{out} *Hybrid* (W)
07.00	592,2	31,92	14,05	4,76	66,84
08.00	690,9	24,20	14,15	5,17	73,14
09.00	923,6	142,63	14,74	10,46	154,12
10.00	1.053,4	303,14	15,8	16,09	254,22
Time (Wita)	P_{in} *Solar Cell* (W)	P_{in} *Wind Turbine* (W)	Hybrid Voltage (V)	Hybrid Current (A)	P_{out} *Hybrid* (W)
11.00	1.163,8	255,37	15,87	15,42	244,68
12.00	1.382,5	60,17	16,68	11,96	199,54
13.00	1.320,6	79,05	16,23	12,70	206,07
14.00	1.040,0	114,20	16,33	10,78	175,96
15.00	519,1	385,42	17,6	14,38	253,01
16.00	488,6	212,91	13,52	8,59	116,17
17.00	359,6	142,63	13,19	6,09	80,35
Output Power			*Average* (W)		165,82
			Minimum (W)		66,84
			Maximum (W)		254,22

In Table 13, the output power measurements were obtained by measuring the voltage and current generated by the hybrid technology of a 200 W solar cell and a 400 W wind turbine on May 31, 2023. The minimum output power recorded was 66.84 W, the maximum was 254.22 W, and the average output power was 165.82 W.

Table 14. Average Power of the Hybrid Power Plant Per Hour

Time (Wita)	*Output Power*							*Average*
	P_{out} (W) H-1	P_{out} (W) H-2	P_{out} (W) H-3	P_{out} (W) H-4	P_{out} (W) H-5	P_{out} (W) H-6	Pout (W) H-7	
07.00	66,84	59,78	52,97	173,86	45,88	74,14	87,41	80,13
08.00	73,14	68,52	73,34	145,68	121,36	94,41	119,61	99,44
09.00	154,12	143,67	240,25	120,03	107,61	104,46	91,24	137,34
10.00	254,22	191,82	298,88	247,56	245,9	204,83	284,19	246,77
11.00	244,68	199,4	249,53	255,15	317,63	213,58	376,18	265,16
12.00	199,54	197,08	251,73	221,5	261,73	229,38	230,47	227,35
13.00	206,07	246,18	246,19	192,46	235,76	211,28	216,6	222,08
Time (Wita)	*Output Power*							*Average*
	P_{out} (W) H-1	P_{out} (W) H-2	P_{out} (W) H-3	P_{out} (W) H-4	P_{out} (W) H-5	P_{out} (W) H-6	Pout (W) H-7	
14.00	175,96	145,44	169,3	215,8	184,09	179,76	166,72	176,72
15.00	253,01	76,26	210,04	178,61	134,28	158,64	147,21	165,44
16.00	116,17	104,75	259,04	120,07	107,25	187,12	301,76	170,88
17.00	80,35	78,85	72,78	285,65	82,98	83,2	135,2	117,00
Output Power				*Average* (W)				173,48
				Minimum (W)				80,13
				Maximum (W)				265,16

In Table 14, the output power measurements were obtained through hourly monitoring of the voltage and current generated by the hybrid technology of a 200 W solar cell and a 400 W wind turbine from May 31 to June 6. The minimum average output power recorded was 80.13 W at 7:00 AM WITA, the maximum was 265.16 W at 11:00 AM WITA, and the overall average output power was 173.48 W

Table 15. Average Power of the Hybrid Power Plant Over 7 Days

Date	*Minimum* (W)	*Maximum* (W)	*Average* (W)
31 Mei 2023	66,84	254,22	165,82
1 Juni 2023	59,78	246,18	137,43
2 Juni 2023	25	298,22	193,09
3 Juni 2023	120,03	285,65	196,03
4 Juni 2023	45,88	317,63	167,67
5 Juni 2023	74,14	229,38	158,25
6 Juni 2023	87,41	376,18	196,05
Output Power	*Minimum* (W)	*Maximum* (W)	*Average* (W)
	25	376,18	173,47

In Table 15, the output power measurements were obtained through periodic monitoring of the voltage and current generated by the hybrid technology of a 200 W solar cell and a 400 W wind turbine from May 31 to June 6. The minimum output power recorded on the 5th day (June 4, 2023) was 25 W at 7:00 AM WITA, while the maximum output power on the 7th day (June 6, 2023) reached 376.18 W at 11:00 AM. The overall average output power was 173.47 W.

Calculation of Hybrid Technology Efficiency

Table 16. Efficiency Measurement Results of PLTH

Time (Wita)	Daya *Input* (W)	Daya *Output* (W)	Efisiensi (%)
07.00	624,12	66,84	10,71
08.00	715,10	73,14	10,23
09.00	1.066,23	154,12	14,45
10.00	1.356,54	254,22	18,74
11.00	1.419,17	244,68	17,24
12.00	1.442,67	199,54	13,83
13.00	1.399,65	206,07	14,72
14.00	1.154,20	175,96	15,25
15.00	904,52	253,01	27,97
16.00	701,51	116,17	16,56
17.00	502,23	80,35	16,00
Efficiency	*Average* (%)		15,97
	Minimum (%)		10,23
	Maximum (%)		27,97

In Table 16, the efficiency measurements were obtained by comparing the Pin of the solar cell, which was derived from solar radiation and the surface area of the solar cell, and the Pin of the wind turbine, which was calculated from the air mass, wind speed, and rotor sweep diameter, with the Pout (output power of the hybrid technology) generated by the 200 W solar cell and 400 W wind turbine on May 31, 2023. The minimum efficiency recorded was 10.23%, the maximum was 27.97%, and the average efficiency was 15.97%.

Table 17. Average Efficiency of PLTH

Time (Wita)	Efficiency							*Average*
	n (%) H-1	n (%) H-2	n (%) H-3	n (%) H-4	n (%) H-5	n (%) H-6	n (%) H-7	
07.00	10,71	12,07	11,14	20,68	7,08	12,17	14,78	12,66
08.00	10,23	11,96	11,6	15,7	12,56	12,42	16	12,92
09.00	14,45	18,42	23,48	12,88	12,24	12,18	12,65	15,19
10.00	18,74	14,94	17,94	16,19	15,76	14,26	17,83	16,52
11.00	17,24	14,38	15,42	15,48	17,82	14,02	21,14	16,50
Time (Wita)	Efficiency							*Average*
	n (%) H-1	n (%) H-2	n (%) H-3	n (%) H-4	n (%) H-5	n (%) H-6	n (%) H-7	
12.00	13,83	13,43	15,04	13,73	15,41	14,11	14,36	14,27
13.00	14,72	14,8	15,03	13,47	14,42	14,11	13,63	14,31
14.00	15,25	13,03	13,81	14,77	15,44	14,44	14,27	14,43
15.00	27,97	8,93	22,17	16,47	16,25	15,92	15,32	17,58
16.00	16,56	18,02	30,84	14,56	16,36	20,16	29,98	20,93
17.00	16	16,95	14,34	32,74	18,53	14,64	20,49	19,10
Efficiency				*Average* (%)				15,86
				Minimum (%)				12,66
				Maximum (%)				20,93

Table 17. Measurement of efficiency obtained through hourly measurements of Pin from the solar cell and wind turbine, and Pout produced by the 400 W hybrid solar cell and wind turbine technology from May 31 to June 6. The minimum average efficiency was 12.66% at 7:00 WITA, the maximum was 20.93% at 16:00 WITA, and the average efficiency was 15.86%.

Table 18. Average Efficiency of the Hybrid Power Plant Over 7 Days

Date	*Minimum* (%)	*Maximum* (%)	*Average* (%)
31 Mei 2023	10,23	27,97	15,97
1 Juni 2023	8,93	18,42	14,26
2 Juni 2023	11,14	30,84	17,34
3 Juni 2023	23,82	32,74	27,90
4 Juni 2023	7,08	18,53	14,71
5 Juni 2023	12,17	20,16	14,40
6 Juni 2023	12,65	38,54	17,31
Output Time	*Minimum* (%)	*Maximum* (%)	*Average* (%)
	7,08	38,54	17,41

In Table 18, the efficiency measurements were obtained through periodic monitoring of the Pin and Pout generated by the hybrid technology of a 200 W solar cell and a 400 W wind turbine from May 31 to June 6. The minimum efficiency recorded on the 5th day (June 4, 2023) was 7.18% at 7:00 AM WITA, while the maximum efficiency on the 4th day (June 3, 2023) reached 32.74% at 5:00 PM WITA. The overall average efficiency was 17.41%.

Tabel 19. *Output Power* PLTS, PLTB, PLTH

Time (Wita)	Panel Output Power (W)	Turbin Output Power (W)	Hybrid Output Powe (W)
07.00	34,64	33,5	80,13
08.00	49,80	34,87	99,44
09.00	59,56	62,82	137,34
10.00	143,63	87,63	246,77
11.00	161,11	83,7	265,16
12.00	181,29	18,74	227,35
13.00	174,82	20,25	222,08
14.00	123,78	30,56	176,72
15.00	48,86	111,96	165,44
16.00	34,13	130,67	170,88
17.00	20,70	87,47	117

Table 20. Efficiency of Solar Power Plants (PLTS), Wind Power Plants (PLTB), and Hybrid Power Plants (PLTH)

Time (Wita)	Panel Efficiency	Turbine Efficiency	Hybrid Efficiency
07.00	6,58	26,69	12,66
08.00	7,4	30,86	12,92
09.00	7,9	35,89	15,19
10.00	11,21	39,41	16,52
11.00	11,49	38,64	16,5
12.00	11,85	28,36	14,27
13.00	11,79	28,86	14,31
14.00	10,95	31,36	14,43
15.00	7,35	39,31	17,58
16.00	6,51	44,77	20,93
17.00	5,45	39,5	19,1

Here are some factors that can influence the output power of solar cell and wind turbine technology:

1. Sunlight Intensity: The output power of solar cells depends on the intensity of sunlight received. Geographic location, seasons, and weather conditions can affect the availability of sunlight, which in turn affects the power generated by the solar cells.
2. Wind Speed: The output power of wind turbines is influenced by wind speed. The higher the wind speed, the more power can be generated by the wind turbine. Therefore, the location where the wind turbine is installed should be carefully selected to maximize the potential for high wind speeds.
3. Energy Conversion Efficiency: The energy conversion efficiency of both solar cells and wind turbines will impact output power. The higher the conversion efficiency, the more energy can be converted into electricity.
4. Capacity of Solar Cells and Wind Turbines: Output power is also affected by the capacity of the solar cells and wind turbines used. The larger the capacity, the more electricity can be generated.
5. Maintenance and Wear Conditions: The sustainability of the output power from both technologies is influenced by proper maintenance and reduced component wear. Well-maintained solar cells and wind turbines will have more consistent and longer-lasting output power.
6. Energy Storage: Energy storage technologies, such as batteries or other storage systems, can impact the output power of hybrid solar cell and wind turbine systems.
7. System Management and Control: Good management and control of the hybrid solar cell and wind turbine system can also affect output power. A system that efficiently maximizes the use of available resources can significantly increase output power.

The changes in efficiency are due to several factors. Here are some aspects that can affect the efficiency of solar cell and wind turbine technologies:

1. Placement: Optimal placement of solar cells and wind turbines can enhance the efficiency of the hybrid system.
2. Sunlight Intensity: Adequate sunlight levels affect the efficiency of solar cells in generating energy.
3. Wind Speed: Sufficient wind speed helps improve the efficiency of wind turbines in generating energy.
4. Maintenance Conditions: Proper maintenance and care of the hybrid system can maintain optimal efficiency.
5. Integration and Control: Effective integration of solar cells, wind turbines, and energy management systems, along with optimal power regulation, can enhance overall efficiency.

All these factors must be carefully considered when designing, installing, and operating solar cell, wind turbine, and hybrid solar cell and wind turbine systems to achieve optimal output power and efficiency. This aligns with relevant research literature (Amalia et al., 2022), which states that as the degree of hindrance factors increases, both output power and efficiency decrease; conversely, as hindrance factors decrease, output power and efficiency increase, as hindrance factors significantly impact technology performance.

CONCLUSION AND RECOMMENDATIONS

By implementing hybrid solar cell and wind turbine technology, the electricity supply needs of aquaculture farmers can be met through the conversion of solar and wind energy into electrical energy. This approach can reduce production costs related to electricity expenditures, as a significant portion of the electricity will be provided by the hybrid solar cell and wind turbine system.

FURTER STUDY

The sustainability design resulting from the implementation of hybrid solar cell and wind turbine technology enables the Tumampua aquaculture group to become self-sufficient and resilient in meeting their electricity needs. This model has strong potential for widespread application among other aquaculture groups in the Boriappaka District of Pangkep Regency, leading to the creation of energy-independent communities and contributing to environmental protection and conservation.

ACKNOWLEDGMENTS

With sincere gratitude, I would like to thank my team for their valuable insights, analysis, collaboration, and recommendations that have significantly contributed to refining this article. We also extend our thanks to the International Journal of Integrative Sciences (IJIS) for allowing us to publish this article.

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