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Design of Continuous Water Heater Hybrid Solar And Gas System

Abstract: *Cooking water using LPG gas is practical and cleaner than using a firebox, but LPG gas is sourced from conventional energy so when the supply of petroleum mines runs out, LPG gas cannot be used anymore, while solar cells use heat from solar energy to meet various needs. very abundant and always there all the time. The purpose of this activity is to produce a continuous solar and gas hybrid system water heater, to know the working principle of the heater and to determine the performance of solar and gas cells in a solar and gas hybrid system continuous water heater. This activity method begins with the design design stage, followed by the manufacturing and assembling stages of the tool, performance testing and ends with the results of testing/data collection. From the test results, it was obtained the results of a continuous water heater hybrid system tool, a solar and gas hybrid system. The efficiency of solar panels is greatly influenced by the size of the intensity of solar radiation or weather. In testing the maximum solar panel efficiency tool is 16.68% with a solar radiation intensity of 1167 W/m2 and a minimum value of 7.28% with a solar radiation of 380 W /m2. The Hybrid system test is able to heat water up to 100 °C with varying efficiency depending on how long it has been used for the Heater and gas. But if you only use a heater, then the maximum water heating that can be achieved is 73.4 °C. This happens because by the time it reaches the water temperature, the power/voltage in the battery has reached its minimum limit (11 V) which is set on the LVD (Low Voltage Disconnect) so that the heater will turn off automatically and the gas (stove) will turn on automatically as well .*

Streszczenie: *Gotowanie wody na gazie LPG jest praktyczne i czystsze niż korzystanie z paleniska, ale gaz LPG jest pozyskiwany z konwencjonalnej energii, więc kiedy wyczerpią się zasoby kopalń ropy naftowej, gaz LPG nie może być już używany, podczas gdy ogniwa słoneczne wykorzystują ciepło z energii słonecznej do zaspokoić różne potrzeby. bardzo obfite i zawsze tam przez cały czas. Celem tego działania jest wyprodukowanie podgrzewacza wody w hybrydowym systemie solarnym i gazowym, poznanie zasady działania podgrzewacza oraz określenie wydajności ogniw słonecznych i gazowych w hybrydowym systemie solarnym i gazowym w ciągłym podgrzewaczu wody. Ta metoda działania zaczyna się od etapu projektowania projektu, następnie etapy wytwarzania i montażu narzędzia, testowania wydajności i kończy się na wynikach testów/gromadzeniu danych. Na podstawie wyników badań uzyskano wyniki działania narzędzia hybrydowego systemu ciągłego podgrzewacza wody, hybrydowego systemu słonecznego i gazowego. Na wydajność paneli fotowoltaicznych duży wpływ ma wielkość natężenia promieniowania słonecznego czy pogoda. W testach narzędzie maksymalnej sprawności paneli słonecznych wynosi 16,68% przy natężeniu promieniowania słonecznego 1167 W/m2 i minimalną wartość 7,28% przy promieniowaniu słonecznym 380 W/m2. Test systemu hybrydowego jest w stanie podgrzać wodę do 100°C z różną wydajnością w zależności od tego, jak długo był używany do podgrzewacza i gazu. Ale jeśli używasz tylko grzałki, maksymalna temperatura wody, jaką można osiągnąć, wynosi 73,4 °C. Dzieje się tak, ponieważ zanim woda osiągnie temperaturę, moc/napięcie w akumulatorze osiągnęło swój minimalny limit (11 V), który jest ustawiony na LVD (Low Voltage Disconnect), dzięki czemu podgrzewacz wyłączy się automatycznie, a gaz (piec) również włączy się automatycznie. (**Projekt hybrydowego systemu słonecznego i gazowego z ciągłym podgrzewaczem wody**)*

Keywords: Hybrid, Water Heater, Solar Cell, Gas, LPG
Słowa kluczowe: Hybryda, Podgrzewacz wody, Ogniwo słoneczne, Gaz, LPG

1. Introduction

Energy at this time has a significant role in human life. Energy is the power that can be used to carry out various process activities [1]. Energy sources can be broadly divided into two groups: non-renewable energy sources (conventional energy) and renewable energy sources [2].

Conventional energy is energy that comes from nature. With the help of technology, it will make this energy be used for energy needs in everyday life [3]. There are many conventional energy sources that humans, including fossil fuels such as oil, coal, and natural gas, can utilize on this earth. However, traditional energy sources are only available in limited quantities on earth and cannot be regenerated. These energy sources will end sooner or later and harm the environment [4].

Like fossil-based energy, renewable energy comes from nature and can be continuously produced without waiting millions of years [5]. Renewable energy comes from elements available on earth in large quantities, for example, the sun, wind, rivers, plants, etc. This energy source is inexhaustible and can be continuously utilized in many parts of the world. If exploited correctly, this energy has the potential to be able to provide the world's current energy consumption needs for a longer time. Solar energy is one of the energies currently being actively developed by the Indonesian government because, as a tropical country, Indonesia has quite a significant potential for solar energy [6]. Of the many energy sources, using solar cells is the most potent alternative to be implemented in Indonesia [7].

Humans have used solar cells that utilize heat from solar energy to meet various needs, such as solar cookers, water heaters, heating, air conditioning, power generation, and solar ovens using sunlight for cooking, drying, and pasteurizing processes [8].

A water heater is used to heat water to a specific hot temperature. A water heater can obtain hot water more efficiently and relatively cheaply than cooking water with a firebox. Boiling water using LPG itself is fast, practical, and cleaner than using a firebox. Still, because LPG gas, which is conventional energy derived from petroleum, cannot be renewed so, when the availability of petroleum mines runs out, LPG cannot be used anymore. Therefore, water heaters using electrical energy have been developed and are widely used by local people, for example, dispensers. The dispenser is a water heater that uses electricity to heat the heating element. Heaters with electric power, such as dispensers, require a monthly fee and are very dependent on electricity, so if the electricity goes out, this electric heater cannot be used anymore, and the price is also relatively high [9].

Solar water heaters are the latest technology and are very innovative in water heating applications . This type is much more effective and efficient in cost, performance, and energy savings. Electric or gas-powered heating requires a monthly fee and is highly dependent on electricity and gas, which are non-renewable natural resources. Meanwhile, solar water heaters utilize abundant sunlight and are renewable natural resources [10].

Several related studies have previously discussed the use of solar power for water heating, such as in [11, 12] concerning the use of solar energy for water heaters by increasing the work efficiency of the heating system, as well as in research [13] using solar power for intelligent water heaters. In addition, an analysis of materials related to increasing the efficiency of solar water heaters was also carried out in research [14, 15]. This research shows that solar energy can be optimized to become valuable something in human life. This research proposes a design and implementation of a water heater based on Hybrid Solar and Gas Power for drinking water needs.

2. Methods

The research began with a literature study on solar and gas hybrids for continuous water heaters. Then design and prepare the tools and materials used. The design is shown in Figures 1 and 2. Figure 1 is the design for the solar panel mount used. Figure 2 is the overall system design.

II.1. Design

The design stage is the first step before applying the Solar and Gas Hybrid System Continuous Water Heater Design. This stage aims to provide an overview of the system that will run and consider several designs so that the Solar and Gas Hybrid System Continuous Water Heater operates optimally.

II.2. Assembly and Manufacturing

The procedures for making and assembling solar and gas panel frames are as follows:

1) Prepare all tools and materials to be used.
2) Making a frame by welding, which will function as a support for solar panels and stoves. This frame is made of L-profile iron.
3) Installing the solar panels on the welded frame.
4) Install SCC, Inverter, MCB DC, and Temodigital on the panel box.
5) Install the indicator light on the panel box door.
6) Install the Relay and Arduino on acrylic, then install them in the panel box.
7) Installing Wattmeter and Peacefair PZEM
8) Installing the Plug on the Inverter and Terminal on the panel box door.
9) Input the program on Arduino to read the heating element's power, voltage, current, and energy.
10) Make a box for the Batteries, so they are easy to parallel.
11) Installing the Stove, Solenoid, Lighter, and Furnace on the circuit board.
12) Install a 12v relay, timer delay, and switch on the box, then install it on the circuit board.
13) Install Heater and Temperature Sensor on the panic cap.
14) Installing the Water Pump on the circuit board.
15) Installing Gas Tubes and Regulators connected to the Solenoid.

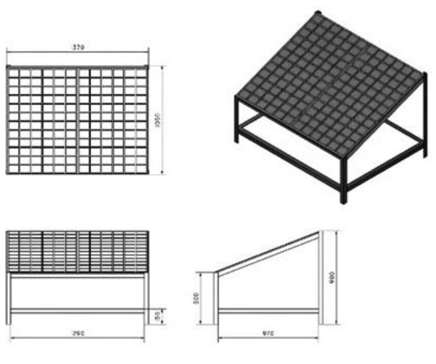


Fig 1. Solar Panel Frame Design

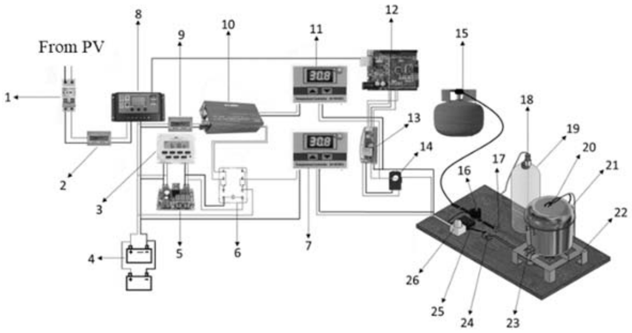


Fig 2. System Circuit Scheme

Caption:

1. MCB DC
2. Wattmeters
3. Digital timer
4. Battery
5. Auto cut off module
6. Omrom relay
7. Thermodigital 12V
8. Solar charge control
9. Wattmeters
10. Inverters
11. Thermodigital
12. Arduino uno
13. PZEM-004T
14. Current transformers
15. 15. Gas cylinder
16. Solenoid valves 12V
17. One-burner stove
18. Water pump 12v
19. Gallons
20. Heaters
21. Temperature sensor
22. Furnace
23. Faucet
24. Electric lighter
25. Boxes
26. Plug and socket

II.3. Tool Testing Procedures

After designing the build is complete, it will proceed with testing the tool and collecting data. Testing and data collection were carried out to determine the output power generated from the Solar and Gas Hybrid System Continuous Water Heater..

1) Prepare tools and materials
2) Assemble solar panels and other equipment according to the circuit drawings.
3) The data collection process from solar cells and batteries is carried out at 10.00-15.00 WITA.
4) Data recorded includes: Solar radiation intensity, solar panel power, solar panel current, solar panel voltage, solar panel energy, battery power, battery current, battery voltage, battery energy, heater power, heater current, heater voltage, heater energy, Mass of gas, the status of heater and stove, temperature of heater and stove
5) Collecting data from gas is carried out at 08.00-15.00 WITA.
6) Measure the initial gas weight after operation.
7) Record the measurement results in the observation table.
8) Data collection is complete.
9) Analyze measurement results.
10) Make conclusions about taking the hybrid system.

Figure 3 shows the prototype of the automatic gas stove used in this study.

3. Result and Analisys

The data from the test results needed are obtained by measuring the quantities in this activity, including:

- Intensity of solar radiation, G (Watt/m2)
- Solar panels output power (W)
- Current (A)
- Voltage (V)
- Solar panel energy (kWh)
- Battery Power (W)
- Battery current (A)
- Battery voltage (V)
- Battery Energy (kWh)

- Heater Power (W)
- Heater Current (A)
- Heater Voltage (V)
- Heat Energy (kWh)
- Water Temperature (°C)
- Mass of a gas cylinder (Kg)

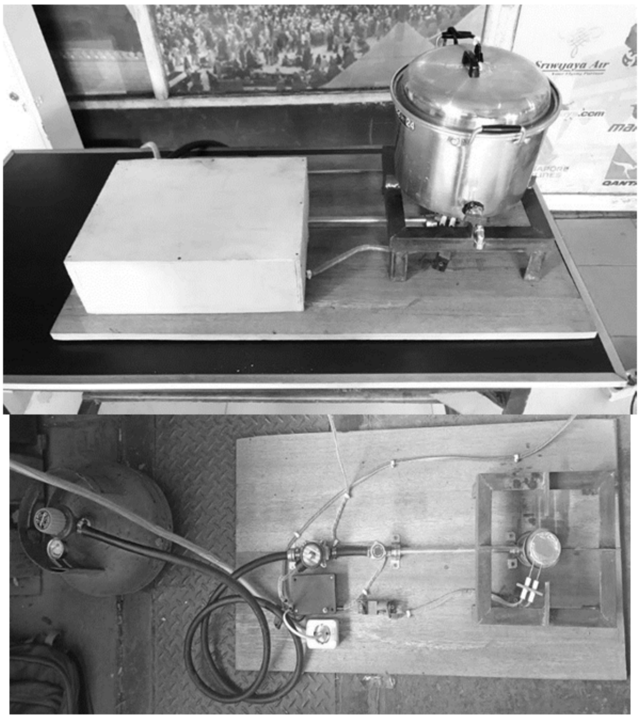


Fig 3. Prototype Kompor Gas Otomatis

Testing is divided into several parts:
1. Testing the heater using solar panels and batteries
2. Testing with gas cylinders
3. Hybrid Heater Testing with Gas

3.1. Data Analysis

3.1.1. Testing the heater using solar panels and batteries

For testing heaters using solar panels and batteries, the data used is in Table 2 in the 9th data.

G = 1002 W/m^2
A = 0.765 m^2
P_{Panel} = 158.1 W
V_{Panel} = 12.37 V
I_{Panel} = 11.58 A
E_{Panel} = 0.151 kWh
$P_{Battery}$ = 270.1 W
$V_{Battery}$ = 11 V
$I_{Battery}$ = 24.59 A
$E_{Battery}$ = 0.261 kWh
P_{Heater} = 279.1 W
V_{Heater} = 200 V
I_{Heater} = 1.40 A
E_{Heater} = 0.410 kWh
T_{Water} = 70.2°C
Status = On

The values obtained are as follows:

a) Solar Panel Input Power (P_{in})
P_{in} = G x A
P_{in} =1002 W/m^2 x 1.530 m^2
P_{in} =1533,06 Watt

b) Solar Panel Output Power (P_{Out})
P_{Out} = V x I
P_{Out} = 12.37 V x 11.58 A
P_{Out} = 143.244 Watt

c) Heater Input Power
P_{in} (Battery) = V x I
P_{in} (Battery) = 11 V x 26,4 A
P_{in} (Battery) = 290,4 W

d) Heater Output Power
P_{in} (Heater) = V x I
P_{in} (Heater) = 200 V x 1.40 A
P_{in} (Heater) = 280 W

e) Panel Efficiency
$\eta_{panel} = \frac{POut\ Panel}{PIn\ Panel}$x 100 %
$\eta_{panel} = \frac{143.244\ \text{Watt}}{1533.06\ \text{Watt}}$x 100 %
η_{panel} = 9.34 %

f) Heater Efficiency
ηHeater= $\frac{POut\ Heater}{POut\ Baterai}$x 100 %
ηHeater = $\frac{280\ Watt}{290{,}4\ Watt}$x 100 %
ηHeater = 96,41%

The results of data analysis are displayed on the graph.

3.1.2. Gas Testing

For testing with gas, the data used is the 3rd data.

T_{1water} = 64,1 °C
T_{2water} = 48 °C
m_{gas_tube} = 7.924 Kg
m_{water} = 5 Kg
Status = On
P = 7,985 kPa
C = 4,2 KJ/Kg

The values obtained are as follows:

a) LPG gas input power
In a 3 kg LPG gas cylinder there is 40% propane gas (C_3H_8) and 60% butane gas, 1 mol C_3H_8 = 2229.3 kjmo-1, 1 mol C_4H_{10} = 2889.1kjmol-1, 1kg LPG contains = 9.1 mol C_3H_8 and 10.34 mol C_4H_{10}
then:
2.924 kg LPG = 9.1 x 2.924 mol C_3H_8 and 10.34 x 2.924 mol C_4H_{10}
= 26.606 mol C_3H_8 and 30.23 mol C_4H_{10}
so the heat energy produced from the LPG gas above is
Q_{in} = n x heat from the combustion reaction
Q_{in} = (n C_3H_8 x combustion reaction C_3H_8) + (n C_4H_{10} x combustion reaction C_4H_{10})
Q_{in} = (26.606 mol x 2229.3 kjmo -1) + (30.23 mol x 2889.1 kjmol-1)
Q_{in} = 146324,4 Kj

b) Gas Output Power
Q_{Out} = m x c ΔT
Q_{Out} = 5 Kg x 4,2 kj/Kg°C x (64,1 °C – 48°C)
Q_{Out} = 338,1 kj

c) Gas efficiency
$\eta_{gas} = \frac{QOut}{Qin}$x 100 %
$\eta_{gas} = \frac{338{,}1\ kj}{146324{,}3\ kj}$x 100 %
η_{gas} = 0,231 %

The results of data analysis are displayed on the graph.

3.1.3. Hybrid heater testing with gas

For testing the Hybrid heater with gas, the data used is the 10th data (the upper limit of the thermodigital is 70°C and the lower limit is 60°C).

G = 924 W/m^2
A = 0.765 m^2

P_{Panel} = 134.2 W
V_{Panel} = 14.36 V
I_{Panel} = 9.4 A
E_{Panel} = 0.152 kWh
$P_{Battery}$ = 291,4 W
$V_{Battery}$ = 11,49 V
$I_{Battery}$ = 25.36 A
$E_{Battery}$ = 0.101 kWh
P_{Heater} = 305,5 W
V_{Heater} = 209,3 V
I_{Heater} = 1.46 A
E_{Heater} = 0.148 kWh
T_{1water} = 65°C
T_{2water} = 61.3°C
Status = On
m_{gas_tube} = 7.708 Kg
m_{water} = 5 Kg
Status = Off
C = 4,2 KJ/Kg

Value values obtained from:

a) Heater Input Power
P_{in} (Battery) = V x I
P_{in} (Battery) = 11,49V x 25.36 A
P_{in} (Battery) = 291.38 Watt
P_{in} (Battery) = 291.38 Watt x 900 s / 1000
P_{in} (Battery) = 262.24 kj

b) LPG gas input power
In a 3 kg LPG cylinder there is 40% propane gas (C3H8) and 60% butane gas (C4H10), 1 mol C3H8 = 2229.3 kjmo-1, 1 mol C4H10 = 2889.1kjmol-1, 1 kg of LPG contains = 9.1 mol C3H8 and 10.34 C4H10 mol
Then:
2.708 kg LPG = 9.1 x 2.708 mol C3H8 and 10.34 x 2.708 mol C4H10
= 24.64 mol C3H8 and 28 mol C4H10
so the heat energy produced from the LPG gas above is:
Q_{in} = n x heat from the combustion reaction
Q_{in} = (n C3H8 x combustion reaction C3H8) + (n C4H10 x combustion reaction C4H10)
Q_{in} = (26.606 mol x 2229.3 kjmo -1) + (28 mol x 2889.1 kjmol-1)
Q_{in} = 135520,1 kj

c) Gas and heater output power
Q = m x c ΔT
Q = 5 Kg x 4,2 KJ/Kg x (65°C – 61.3°C)
Q = 77,70 kj

d) Hybrid Efficiency
$\eta_{Hybrid} = \frac{Qout}{Qin}$ x 100 %
$\eta_{Hybrid} = \frac{77,70\ kj}{135520,1\ kj + 262.24\ kj}$ x 100 %
η_{Hybrid} = 0,06%

The results of data analysis are displayed on the graph..

3.2. Graph and Discussion

3.2.1. *Solar Panels*

Figure 4 shows the relationship between solar panel input power and time, where the input power of solar panels tends to fluctuate, or the graphic trend fluctuates (up/down). This is due to changes in solar radiation intensity or weather changes. The maximum value of solar panel input power occurs at 12.15 with an input power of 1785.51 Watt, and the minimum value of solar panel input power occurs at 12.45 with an input power of 581.4 Watt.

Figure 5 shows the relationship between the output power of the panel against time, where the output power of the solar panel tends to change or the graphic trend fluctuates (up/down). The maximum solar panel input power value occurs at 12.15, with an output power of 184.06 Watts. The minimum solar panel input power value occurs at 59.33 Watts with output power.

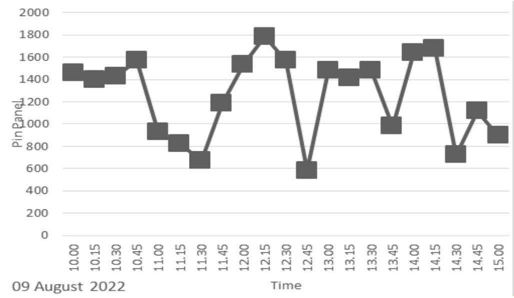
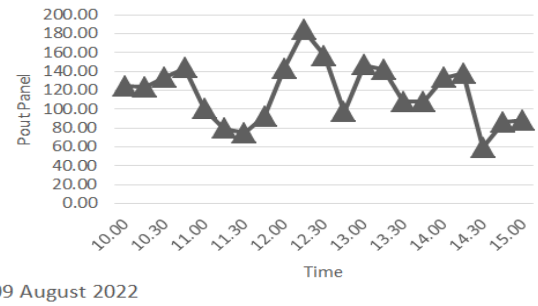


Fig 4. Graph of Panel Input Power relationship to Time



F
ig 5. Graph of the panel output power relationship to time

Figure 6 shows the relationship between solar panel efficiency and time, where the efficiency of solar panels tends to fluctuate, or the graphical trend fluctuates (up/down). The maximum value of solar panel efficiency occurs at 12.45 with an efficiency of 16.68%, and the minimum value of solar panel efficiency occurs at 13.30 with an efficiency of 7.28%.

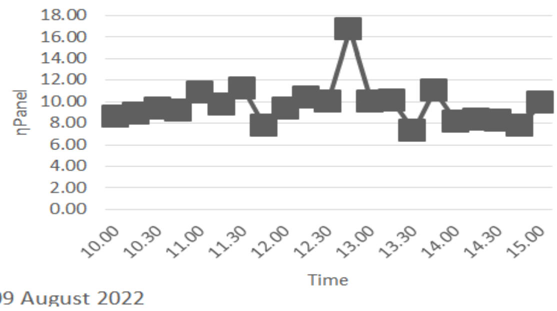


Fig 6. Graph of the relationship between panel efficiency and time

3.2.2. LPG Gas Cylinders

Figure 7 shows the relationship between gas input power and time, which is inversely proportional (the graph trend is decreasing). The longer the gas ignition time, the less input power of the gas will decrease. The maximum input power occurs at 10.00 with a value of 400340.3 Kj, and the minimum value occurs at 15.00 with a value of 388430.2 Kj.

Figure 8 shows the relationship between gas output power and time. Namely, the trend of the graph fluctuates (up and down). The greater the value of the change in water temperature in the pan, the higher the gas output power and vice versa. The duration of gas ignition influences this. The graphic image above shows that the relationship between gas input power and time is inversely proportional (the graphic trend is decreasing). The longer the gas ignition time, the less input power of the gas will decrease. The maximum output power occurs at 10.15 with a value of 373.8 Kj, and the minimum value occurs at 10.00 with a value of 0 Kj.

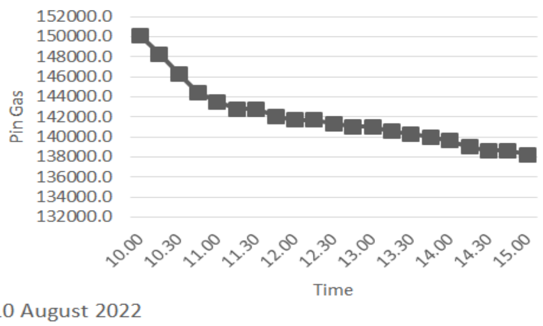


Fig 7. Graph of the relationship between gas input power and time

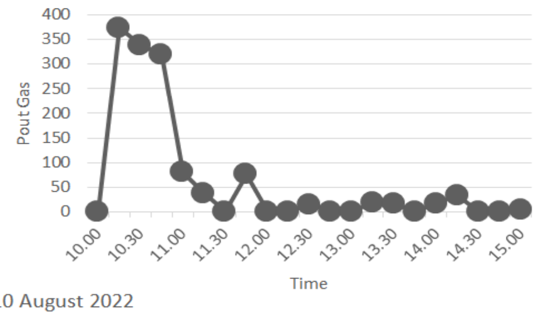


Fig 8. Graph of the relationship between gas output power and time

Figure 9 shows the relationship between gas efficiency and time, which is not directly or inversely proportional but fluctuating. The maximum value of gas efficiency occurs at 10.15 with a value of 0.252%, and the minimum value occurs at 10.00 with a value of 0%.

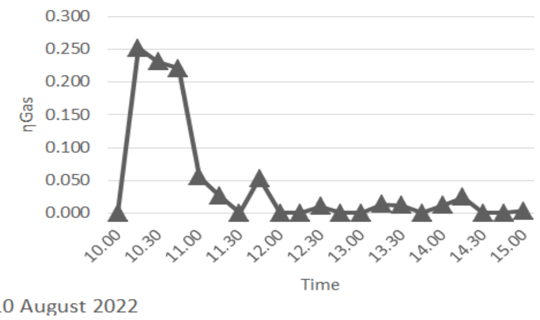


Fig 9. Graph of the relationship between gas efficiency and time

3.2.3. Hybrid

Figure 10 shows that the relationship between heater input power and time is not directly or inversely proportional but has a relationship or graphic trend that goes up and down. The maximum value of the heater input power occurs at 12.15 with a value of 271.908 Kj, and the minimum value occurs at 8.30 with a value of 3.324 Kj.

Figure 11 shows the relationship between gas input power and time, which is inversely proportional (the graph trend is decreasing). Where the extended gas ignition time is, the input power of the gas will decrease, and the input power from 9.30-15.00 is always the same because the stove/gas is off. the maximum input power occurs at 10.00 with a value of 140124.2 Kj. The minimum value occurs at 15.00 with a value of 135520.1 Kj.

Figure 12 shows the relationship between hybrid output power and time, which is not directly or inversely proportional but fluctuating. The maximum value of gas efficiency occurs at 8.30 with a value of 373.80 Kj, and the minimum value at 15.00 with a value of 0 Kj.

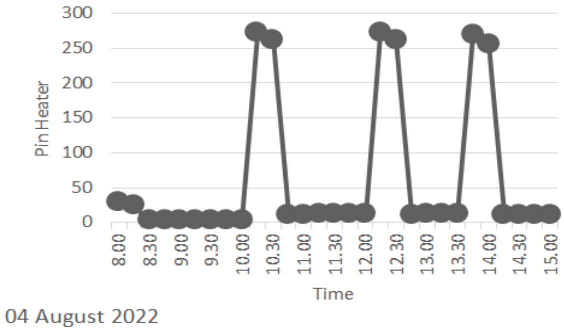


Fig 10. Graph of the relationship between heater input power to time

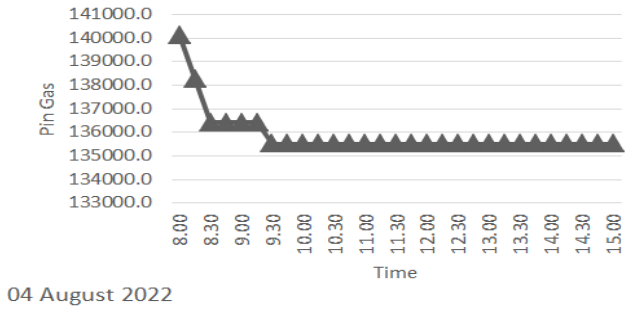


Fig 11. Graph of the relationship between gas input power and time

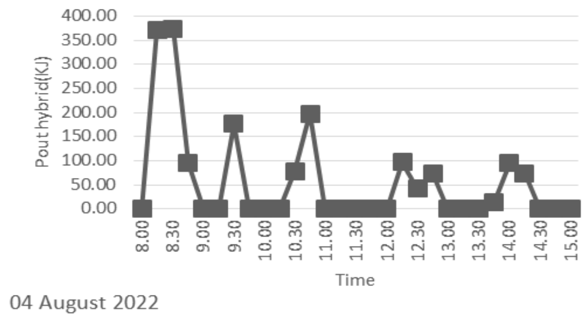


Fig 12. Graph of hybrid output power against time

Figure 13 shows the relationship between hybrid efficiency and time, which is not directly or inversely proportional but fluctuating. the maximum value of hybrid efficiency occurs at 10.45 with a value of 0.274% and the minimum value at 15.00 with a value of 0%.

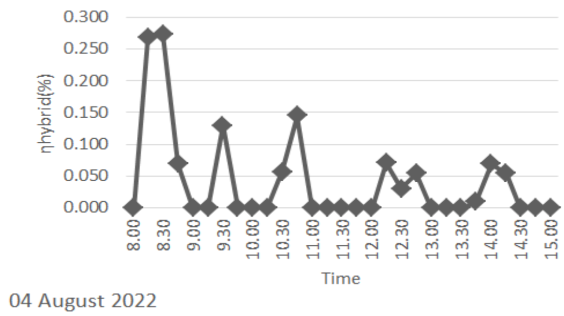


Fig 13. Hybrid efficiency graph over time

4. Conclusion

From the results of the discussion in the previous chapter, the following conclusions can be drawn:

1. The results of a continuous water heating system tool, a solar and gas hybrid system, are obtained.

2. The size of the intensity of solar radiation or weather dramatically influences the efficiency of solar panels. In testing, the maximum solar panel efficiency tool is 16.68% with a solar radiation intensity of 1167 W/m2 and a minimum value of 7.28% with a solar radiation of 380W/m2.

3. Hybrid system test can heat water up to 100 °C with an efficiency that varies depending on how long it is used than Heater and gas. But if you only use a heater, the maximum water heating achieved is 73.4 °C. This happens because when it reaches the water temperature, the power/voltage in the battery has reached its minimum limit (11 V), which is set on LVD (Low Voltage direct) so that the Heater will turn off automatically. The gas (stove) will turn on automatically too.

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