Prototype Thermoelectric Micro Energy By Utilizing The Heat Of A Sate Stove

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***Abstract*— Electrical energy is one of the primary needs that is very important in people's lives. Along with advances in science and technology (IPTEK) and rapid population growth, the need for electrical energy increases every day. However, research on the use of thermoelectric technology to harvest energy from the heat of satay stoves is still limited and has not been widely applied in renewable energy systems. The aim of this research is to design an energy harvester that utilizes waste heat from a satay stove using a thermoelectric module, so that enough power and voltage can be produced to operate a 12-volt 1-ampere DC fan The research results show that the Thermoelectric Generator (TEG) is capable of producing the highest voltage of 10V with a current of 1.06A at the highest temperature difference of 100°C. By using the Buck-Boost Converter module, the voltage can be increased to 12.6V with a current of 1A. Apart from that, this research also found that the greater the temperature difference from the furnace heat source, the greater the voltage produced by the TEG. When charging the battery, it takes 7 hours to charge from the initial voltage of 11.31V to reach 12.60V, and using the battery for 5 hours shows a decrease in voltage from 12.60V to 11.41V. Thus, utilizing the waste heat energy from satay stoves using thermoelectricity is a solution to help with the power needs of traders. And in the future it can be done with different sources to develop research and increase effective output power.**

Keyword - Thermal electric generator; Microgrid; Boost converter; series and parallel Circuit; Buck-boost converter.

I. INTRODUCTION

Increasingly advanced technological developments will have an impact on changes in the human population. This creates pressure on energy sustainability in Indonesia and highlights the importance of looking for more environmentally friendly and sustainable alternatives In recent years, electrical energy has become a crucial issue in the world. Electrical energy consumption is increasing from year to year throughout the world [1]. The supply of electrical energy from crude oil, natural gas and coal is currently limited. This is because these materials cannot be renewed. Thousands of scientists are competing to save energy and produce renewable energy that can be used directly by local communities. Currently, thermal power plants are being developed to produce electrical energy from waste thermal energy. Devices with this function are Peltier elements, or more often called thermoelectric elements, which operate on the principle of the Seebeck effect [2].

Most satay traders still rely on manual fans or have to use electricity from PLN, which of course requires additional expenses. However, to overcome this problem, there is great potential in utilizing the heat produced during the combustion process in satay stoves as a source of electrical energy [3]. Utilizing the heat energy that arises during furnace combustion into electricity is a promising solution. This technology uses a thermoelectric generator (TEG) which can take heat as an energy source, which is one of the green technologies that has an important role as an alternative energy source in the future[4]. TEG technology has a number of advantages, such as high durability, operation without sound because it has no moving mechanical parts, does not require intensive maintenance, is simple, compact, safe, small in size and light, can operate at high temperatures, is suitable for small scale and remote areas, is environmentally friendly, and is an energy source that can be adapted to needs.

The from previous research conducted by Moh. Masid entitled "Utilization of wasted pot heat as an alternative source of electrical energy based on thermoelectric generators (teg)" it was concluded that the researcher got results of 2.2V, 0.46A, 1.41W and 4.78Ω with a medium light without the addition of a boost converter [5]. Another study using 2 Thermoelectric with a series circuit produced 3.4 V at a current of 2.8 mA, the highest See-beck coefficient calculated was 0.226 V/K. The boost module makes it possible to increase the voltage to 12.6 V at load, and reduce the voltage to 10.5 V at current flow. Up to 9-10mA. The voltage generated by the TEG decreases as the distance from the exhaust heat source increases. The output from this thermoelectric element has been able to power a 12V motorcycle light according to previous research. Additionally, the use of thermoelectric generators has also been applied to various heat sources based on several existing studies The aim of this research is to design an energy harvester that utilizes waste heat from a satay furnace using a thermoelectric module, so that enough power and voltage can be generated to operate a 12-volt 1-ampere DC fan[6][7].

II. STUDY LITERATURE

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The research entitled "*Rancang Bangun Pembangkit Listrik Alternatif Menggunakan Termoelektrik dengan Memanfaatkan pada Tungku Pemanas*" [8] successfully utilized a boost converter by producing a voltage of 42.8V at a temperature difference of 90°C. In comparison, using a 5W D.C. lamp load will produce a voltage of 8.81V at a temperature difference of 82°C and a current of 0.6A. Moreover, it produces a power of 4.84W. The study entitled "*Generator Termoelektrik Dengan Memanfaatkan Panas Yang Terbuang Dari Api Pembakaran Untuk Pengisian Baterai Handphone*" [9] succeeded in making a circuit by utilizing eight thermoelectrics into series and parallel circuits by producing a voltage of 4v and a battery charging current of 0.17A when the battery has a capacity of 50% with a charging time of 4 hours 42 minutes with a temperature of 31.9 ° C to a temperature of 32 ° C. then when the temperature reaches 48 ° C to a temperature of 50.1 ° C, the resulting voltage is 4.2v and the battery charging current is 0.34A. The battery has a capacity of 50%, a charging time of 2 hours and 21 minutes, and an 800mAh battery. However, the tool to achieve maximum results uses a T.E.G. module, which is more heat resistant and produces higher power than TEC1-12706. To produce a large voltage, a better cooling system is needed. Another study entitled "*Pemanfaatan Panas Panci Yang Terbuang Sebagai Sumber Energi Listrik Alternatif Berbasis Termoelektrik Generator (TEG)"* [10] successfully utilized the heat of a stainless steel pan by producing a voltage of 2.2v, a current of 0.64A, a power of 1.41w and a resistance of 4.78Ω and modifying the pan lid so that the thermoelectric generator can absorb the wasted heat to the maximum.

A. Thermoelectric

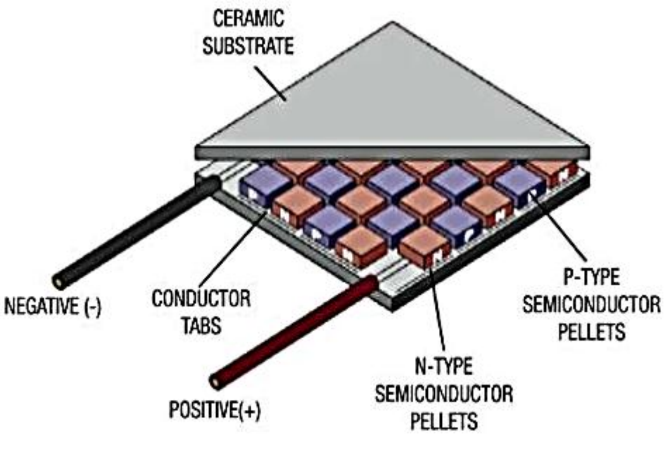

Figure 1 Termoelektrick

Thermoelectric technology is technology that converts heat energy directly into electrical energy (thermoelectric generator) or vice versa to produce cold air (thermoelectric cooler) [11]. To generate electricity, it is enough to insert thermoelectric material into a circuit that connects hot and cold sources The principle of operation of a thermoelectric element is based on the "Seebeck effect", that is, when two dissimilar metals are connected at one end, the connection is given a different temperature giving rise to a voltage difference at one end of the other end [1]. Semiconductor materials are commonly used to generate electricity [12]Semiconductors are materials that can conduct electricity but not perfectly, the semiconductors used are n-type and p-type semiconductors. Semiconductors used are materials that are able to work at high temperatures[13].

B. Heatsinks

Heatsinks are very influential in controlling heat and absorbing heat better [14]. The size of the heatsink must follow the location of the heat and cold source that will be used. In the cooling process, the heatsink is usually equipped with a cooler so that the heatsink heat can be controlled.

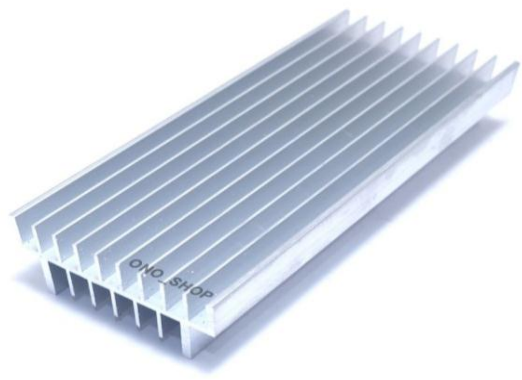

Figure 2 heatsink

The function of the heat sink is to control or cool the thermoelectric installed in the satay stove so that thermoelectric performance is maximum.

C. Buck-boost converter

Buck-boost converter is a type of DC-DC converter that is used to convert DC voltage to a higher or lower value, depending on the system requirements. The main way a buck-boost converter works is by using an electronically controlled duty cycle to regulate the output voltage[15].

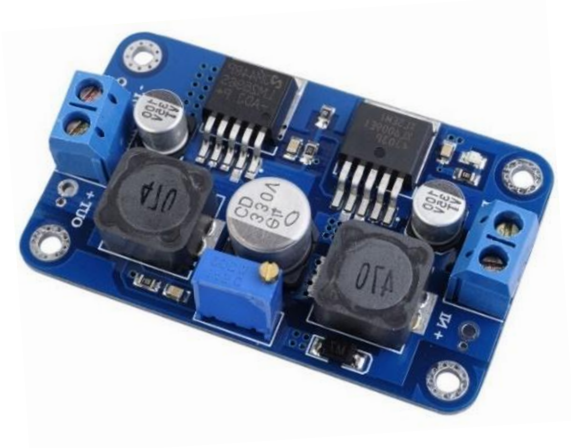

Figure 3 buckboost converter

D. BMS 3S

Battery Battery Management System (BMS) can be a very important protector for the battery [16]. BMS is an electronic system specifically designed to manage and monitor battery performance. Its main role is to ensure optimal charging and use of the battery, as well as to protect the battery from damaging conditions such as over-charging, over-discharging, unsafe temperatures, and excessive current [17][18].

Figure 4 bms 3s

III. METHODOLOGY

This research begins with identifying problems and developing ideas for utilizing thermoelectricity as an alternative energy source, followed by a literature study that focuses on making tool designs. then designing and assembling components, researchers conduct trials and repairs to ensure the tool runs and functions optimally or not. After the device functions properly, data collection and analysis are carried out to obtain conclusions and suggestions for further development. Hardware planning and manufacturing refers to the system block diagram that will be used as follows.

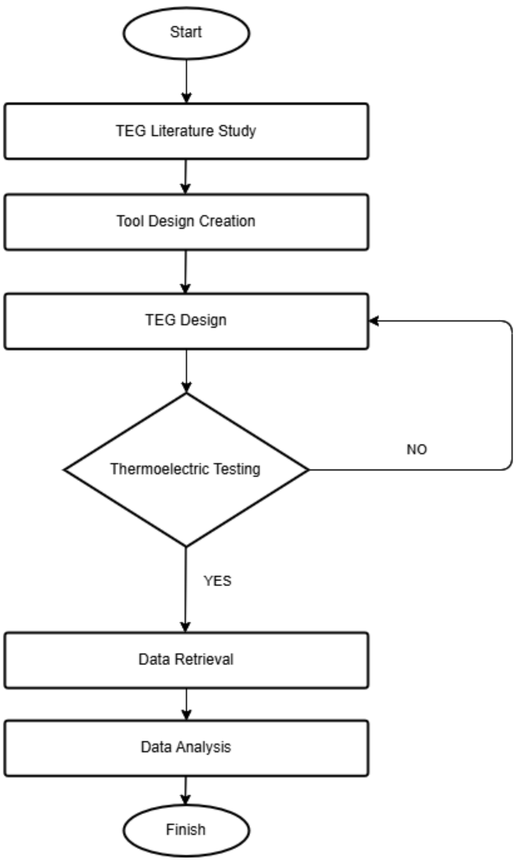

Figure 5 flowchart system

This research begins with identifying problems and developing ideas for utilizing the heat of a satay stove as an energy harvester using a thermoelectric module, followed by a literature study that focuses on the use of thermoelectric modules After designing and assembling the components, the researcher conducts trials and repairs to ensure that the thermoelectric functions collection and analysis are carried out to obtain conclusions and suggestions for further development. Hardware planning and manufacturing refers to the system block diagram that will be used as follows.

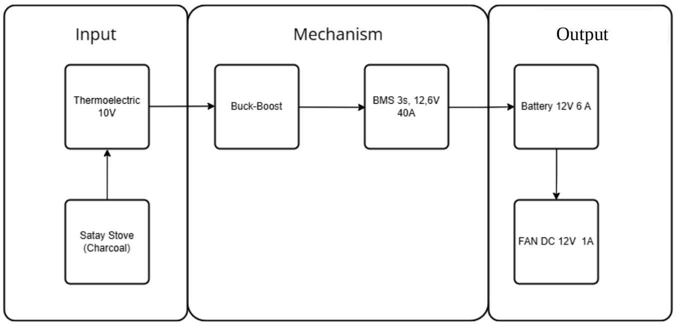

Figure 6 Diagram of the System

From the block diagram above, it can be seen that from the image above, it can be explained that the system input is the satay stove heat which is given to the thermoelectric element, and the heatsink functions as a cold source. The process begins by heating the satay furnace, and the furnace temperature is measured to around 40-130°C using a series and parallel circuit. The mechanism from the picture above can be explained that the thermoelectric is assembled first with 5 series circuits and followed by 5 parallel circuits. Then data is collected, namely the results of voltage, current and power. The use of a buck boost converter with auto buck/boost on thermoelectric generators aims to stabilize the energy produced by the thermoelectric generator so that it is at the maximum working point, even though there are changes in load or temperature changes caused by external factors. In this research, the energy produced by a thermoelectric generator will be stored in a battery. Therefore, the maximum working point of the thermoelectric generator is adjusted to the nominal voltage for charging the battery which will be used to start the 12 volt 1 ampere fan.

A. Device System Design

The system consists of several main components. First, there are five Peltier modules assembled in series and parallel configuration. These Peltier modules function to convert the temperature difference into electrical energy [19]. The generated electrical energy is then flowed through diodes, which serve to prevent reverse current and protect the circuit from potential damage. After going through the diode, the electric current is directed to the buck-boost converter, which is responsible for stabilizing the output voltage as needed.

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Finally, the electrical energy that has been regulated by the buck-boost converter is stored in a 12V 6Ah battery, which can be used to operate other devices [20].

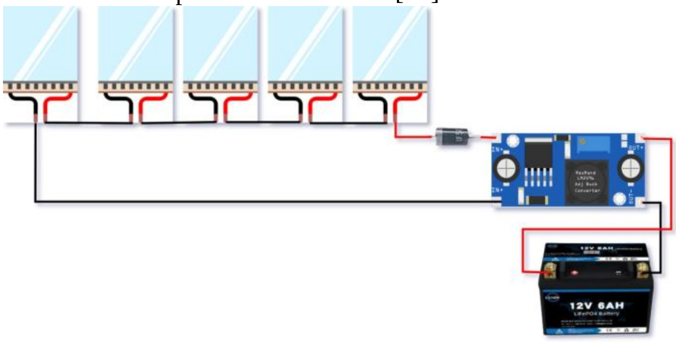

Figure 7 TEG Serial Circuit design

B. *Tool Design*

In the design of this device, the working principle used is as follows: Five thermoelectric modules are assembled in series and parallel configurations, with five modules in each configuration [21]. The modules are then connected to a buck-boost converter to generate electrical energy. After the energy is generated, the power obtained will be channeled to a 12-volt DC fan. Furthermore, measurements are taken to determine the amount of power generated by each thermoelectric module in the series and parallel circuits [22].

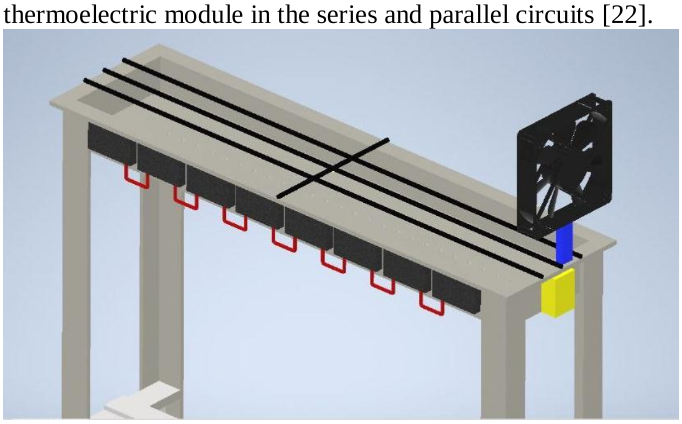

Figure 8 3D design

C. *Battery Charging Planning*

The battery used is a 12 Volt/6Ah. A battery can be larger if Vch>V battery. Determine the battery charging voltage and current: If each 12 Volt battery has 4 cells, then the battery must be charged with a voltage of:

Vch = 3 x cell battery
= 3 x 4
= 12 Volts

IV. RESULTS AND DISCUSSION

In this chapter, we will test the tools that were assembled in the previous chapter. This research aims to determine the efficiency of the power produced by thermoelectric to power the fan by utilizing the heat produced by the satay stove.Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

In this research, 5 thermoelectric units were used which will be arranged in series and parallel to get a comparison. Where:

1. Thermoelectric = 2 volts 0.2 amperes.

- Series: Vseries = 2V × 5 = 10V
- Parallel: Vparallel = 1 × 5 = 5V

Information:

- I = Current Strength (Ampere)
- V = Voltage (Volts)

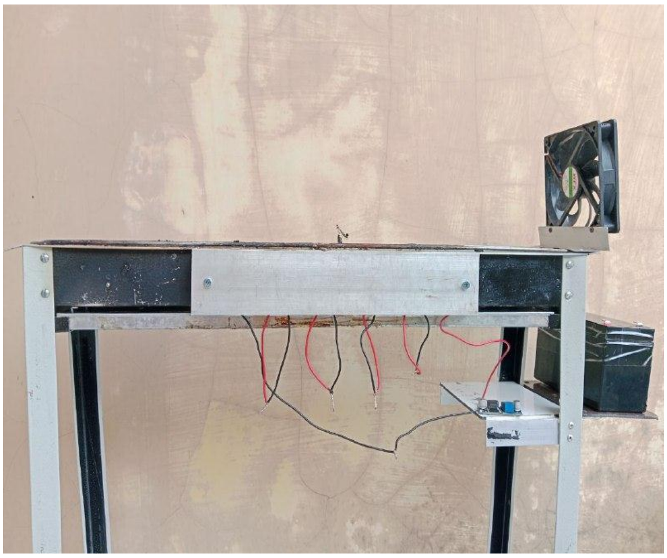

Figure 9 Final product

A. *Series Circuit*

From the data in the table 1, it can be seen that the amount of voltage produced by thermoelectrics in a series circuit where the temperature difference starts from 45 °C to 100 °C increases with increasing temperature difference where the voltage is 10 volts and the current is 1.60 Amperes

Table 1 Series Circuit Measurement Based on ΔT (°C)

No	Hot Temp (°C)	Cold Temp (°C)	ΔT (°C)	Volt (V)	Curr (A)	Power (watt)
1	45	30	15	0.62	0.4	0.25
2	54	30	24	1.1	0.46	0.51
3	62	30	32	4.48	0.52	2.33
4	69	31	38	6.85	0.58	3.97
5	77	31	46	6.97	0.64	4.46
6	84	31	53	8.69	0.7	6.08
7	92	31	61	9.14	0.76	6.95
8	99	31	68	9.17	0.82	7.52
9	107	30	77	9.24	0.88	8.13
10	114	30	84	9.66	0.94	9.08
11	122	30	92	9.75	1	9.75
12	130	30	100	10	1.06	10.60

From the Figure you can see a series circuit where the red cable and black cable up to 5 thermoelectric are connected. The increasing temperature range produces a more significant power value. The difference can be seen in experiment 1, with a temperature range of 15 0C, producing a power value of only 0.25 Watts. In contrast, experiment 12, with a temperature range of up to 100 0C, can produce power up to 10.6 Watts. When the temperature observation temperature value gets more expansive, the power can also increase in each experiment. The experiments influence T.E.G.'s temperature range value to produce maximum power outside the T.E.G. material used. In line with that, the temperature range significantly affects the current and voltage values. The greater the range value, the higher the voltage and current values, and vice versa.

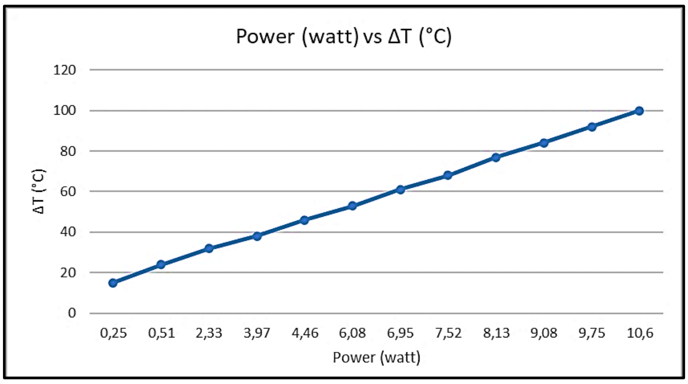

Figure 10 Power (watts) vs ΔT (°C) graph in TEG Serial Citcuit

B. Parallel circuit

In parallel thermoelectric measurements, the results show that the voltage value is the same and the current value increases. Seen in the table above, the voltage value is only in the range 0.62V to 1.17V with a temperature difference that is not much different. Meanwhile, in terms of current value, even though it gets a low output of 0.40A with 5 modules connected in parallel, it gets an output of 1.7 watts. It can be concluded that in a parallel circuit the voltage will be the same but the current will increase even with a low output.

Table 2 Parallel Circuit Measurement Based on ΔT (°C)

No	Hot Temp (°C)	Cold Temp (°C)	ΔT (°C)	Volt (V)	Curr (A)	Power (watt)
1.	45	30	15	0.51	0.40	0.20
2.	54	30	24	0.57	0.44	0.25
3.	62	30	32	0.63	0.48	0.30
4.	69	31	38	0.69	0.52	0.35
5.	77	31	46	0.75	0.55	0.41
6.	84	31	53	0.81	0.60	0.48
7.	92	31	61	0.87	0.63	0.54
8.	99	31	68	0.93	0.68	0.63
9.	107	30	77	0.99	0.73	0.72
10.	114	30	84	1.05	0.76	0.79
11.	122	30	92	1.11	0.81	0.89
12	130	30	100	1.17	1.00	1.7

In parallel thermoelectric measurements, the results show that the voltage value is the same and the current value increases. Seen in the table above, the voltage value is only in the range 0.62V to 1.17V with a temperature difference that is not much different. Meanwhile, in terms of current value, even though it gets a low output of 0.40A with 5 modules connected in parallel, it gets an output of 1.7 watts. It can be concluded that in a parallel circuit the voltage will be the same but the current will increase even with a low output.

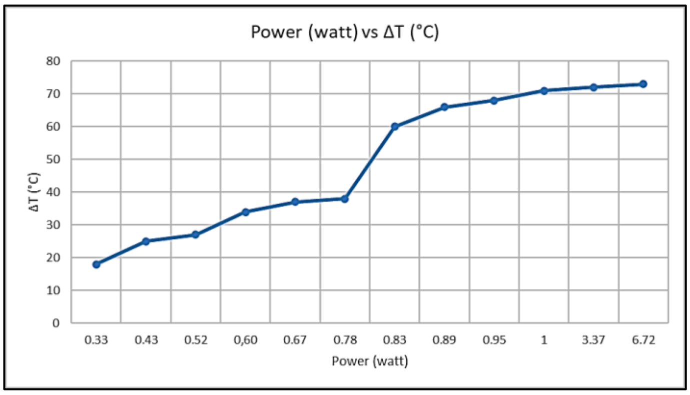

Figure 11 Power (watts) vs ΔT (°C) graph in TEG Paralel Citcuit

C. Battery Charging

The voltage on the buck-boost converter is from 11.79 volts to 12.25 volts. In the buck-boost converter voltage range it is considered capable of charging the battery. at 8 volts, then at buck-boost voltage the voltage output will still be read. So it can be concluded that the voltage can increase from the thermoelectric to the buck-boost converter, but the current in the buck-boost converter is lower than the thermoelectric. This is because the input power is greater than the output power on the buck-boost converter. In this test, data is measured every 30 minutes to see the charging carried out with the thermoelectric circuit. At the beginning of the measurement, it showed an initial voltage of 7.80 V with a power of 3.27 W. After increasing the charging time, there was an increase in the voltage and power produced. The buck-boost converter also gets a fairly stable output, starting from 11.79 V and reaching 12.25 V. Next, the battery with a capacity of 10% is gradually filled with increasing power.

Table 3 Battery charge measurement

Time (minutes)	Pin (watt)	Vout BB Converter	Pout (watt)	Vbatt (volt)	capacity (%)
16.00	11.45	12.00	10.68	11.31	10
16.30	11.46	12.40	10.91	11.41	10.08
17.00	11.56	12.53	11.03	11.51	10.17
17.30	11.56	12.53	11.15	11.61	20.05
18.00	11.60	12.61	10.84	11.71	20.22
18.30	11.59	12.67	11.28	11.81	30.15
19.00	11.56	12.69	11.04	11.91	40.03
19.30	11.67	12.62	10.98	12.01	40.36
20.00	11.67	12.62	10.85	12.11	50.20
20.30	11.72	12.65	10.88	12.21	60.04
21.00	11.70	12.67	11.02	12.31	69.94
21.30	11.72	12.52	10.77	12.42	80.51
22.00	11.72	12.52	10.89	12.50	90
22.30	11.84	12.50	11.00	12.60	100

From the figure 12, it can be seen that there is an increase during battery charging where the initial battery capacity is 10% to 100% full.

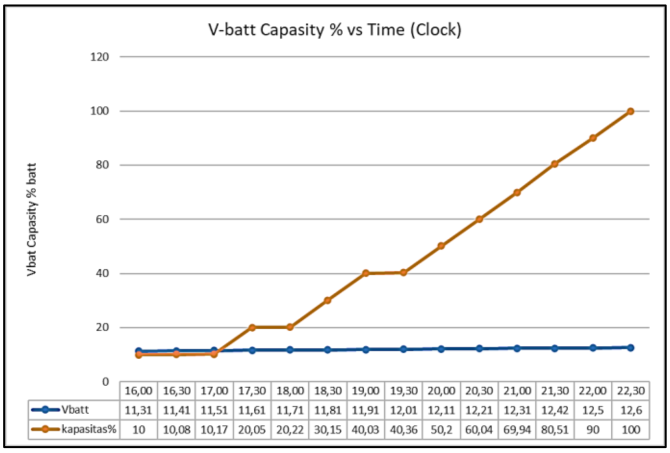

Figure 12 Vbatt capacity % batt vc time (clock)

Based on the experiments conducted, the T.E.G. circuit's input power to the battery can rotate the D.C. fan to work optimally. The fan lights the charcoal embers and keeps them burning while the T.E.G. reabsorbs the remaining heat and recycles it to produce micro-electricity, returning to the battery. These results will provide added value in utilizing waste heat in the satay stove.

Figure 13 Battery Charging

V. CONCLUSION

Based on tests carried out on 5 thermoelectric modules connected in series, the results obtained were a voltage of 10V with a current of 1.06 A. Meanwhile, when connected in parallel, a voltage of 1.17V with a current of 1A was obtained. The conclusion of this test shows that the series arrangement increases the voltage while the current remains constant, while the parallel arrangement increases the current with a lower voltage. During battery testing, it was discovered that the starting voltage of the battery was at 11.31V. After charging for 7 hours, the battery voltage increases to 12.60V, indicating that the battery is fully charged. In this process, the battery capacity which was initially only 10% managed to increase gradually until it reached 100%. Testing the use of the battery with a fan load of 12 volts and a current of 1 ampere, there was a decrease in battery voltage and capacity after 30 minutes. Where, the battery had a voltage of 12.60 volts with a power of 12.60 watts and a current of 1 ampere, and a full battery capacity, namely 100%. However, after the fan load was used for 30 minutes, the voltage decreased to 11.41 volts, with the current remaining at 1 ampere. Battery capacity also decreased by 10.08%.

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