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# Development of Thermal Energy Harvesting from Air Conditioner for Self-Powered Smart Home Appliances

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**Abstract:** Recycling energy is a viable option for establishing a green environment in today's society. Air conditioner consumes the most energy on a global scale. Air conditioner is commonly used to maintain a comfortable interior temperature. Split unit air conditioner systems are popular in Malaysia for small-area applications. The heat released by the condensing unit, on the other hand, is lost to the environment. Therefore, one Peltier device was created in this project utilising a thermoelectric generator (TEG) module. This study aims to develop a Peltier device to harvest thermal from a condenser unit and converting it into usable electricity. The Peltier device was sandwiched between two aluminium plates. The sandwiched TEG is placed at two different locations which are at the discharge pipe and the heat tank. The best location will be chosen based on the effectiveness and performance of the TEG. Five Peltier were placed between aluminium plates in random order. The testing result show that after 30 minutes of operation, the split unit air conditioner produced a maximum of 3.00 V. The 3.00 V is then stepped up to 13.00 V which is used to charge the battery. The voltage from the battery is then directed to the socket outlet with the help of an inverter. The objective of this project has been achieved. The use of TEG to gather heat and convert it to power demonstrates that a heat recovery is a viable option. The current generated is suitable for home appliances usage.

**Keywords:** Air Conditioning, Thermoelectric Generator, Peltier Device, Energy Harvesting

## 1. Introduction

The majority of the nations in the developing countries are now undergoing significant population and urban expansion. The majority of Asian countries undergo a hot, humid environment for the bulk of the year [1]. During the last several decades, the usage of air conditioner in residential buildings has increased dramatically. According to the International Energy Agency as of 2018, 1.6 billion air conditioner units were installed which ended up for an estimation of 20.00 % energy usage in a building

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globally [2]. Figure 1 shows the overall demand for air conditioner in Malaysia from 2012 to 2018. From the figure can conclude that the usage of air conditioner in Malaysia is increasing rapidly for the past few years. [3]

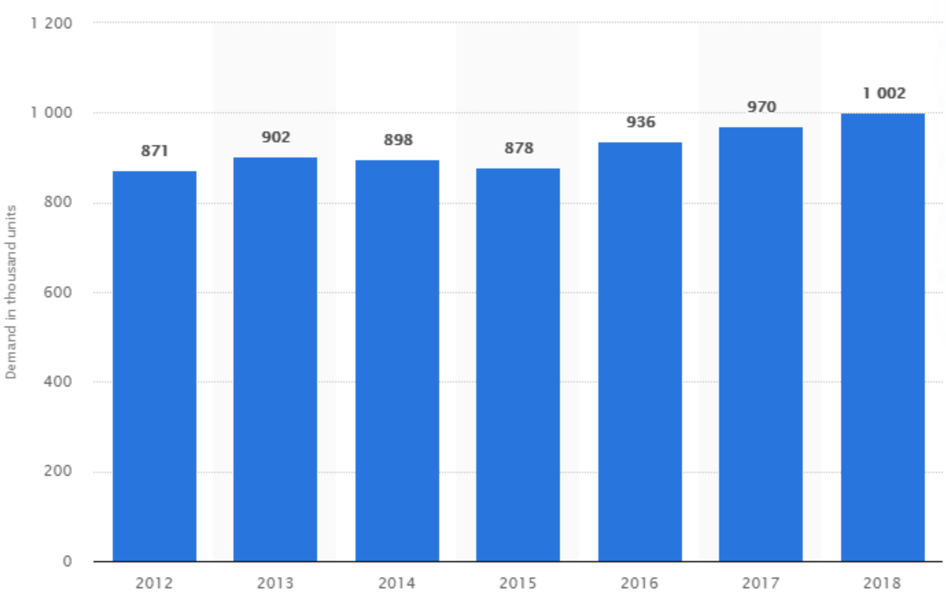


**Figure 1: Overall demand for air conditioners in Malaysia from 2012 to 2018 [3]**

An air conditioner cools your home by sucking heat out and sending it to a compressor positioned outside the building, where it is subsequently replenished with cooler air. The cooling cycle's heart is the compressor. The compressor will start the cycle by drawing cool gas from the interiors, which is low-pressure refrigerant gas [4]. The primary purpose of the motor-driven compressor is to crush the refrigerant, increasing its temperature and humidity. As a result, the high-pressure gas will leave as hot gas via the compressor.

The heated gas is pushed by the compressor to the grooved condenser coil from the outside side of the compressor , where fans blow cool outer air over the coils and through the fins, removing heat from the refrigerant and transferring it to the outside air[ 4][5]. Recycling energy is among the most critical aspects of achieving a green environment in today's society. As a result, air conditioner would consume the most energy on the planet. Solar energy, wind energy, hydro energy, nuclear energy, and many more forms of renewable energy can be taken as an example [6].

Figure 2 shows a research in the year 2011 where it clearly states the most usage of home appliances based on terrace houses. The usage of air conditioner is recorded at a 65.00 %, and this proves that a big amount of energy is being wasted [7]. As was said previously, every user is unaware of the amount of energy generated by the air conditioner, and so it is abandoned. By turning the energy into useable electricity, the user could save money on electricity while simultaneously reducing the ozone layer's thinning.

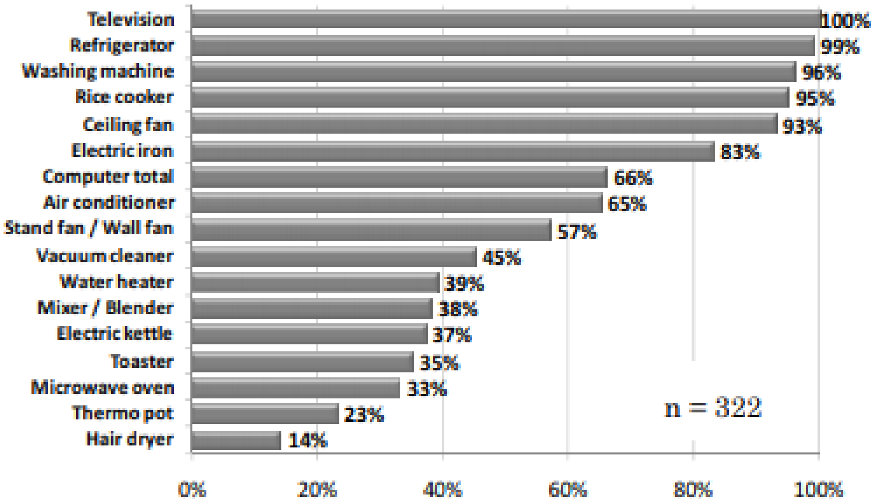


**Figure 2: Usage of air conditioner among terrace household [7]**

### 1.1 Problem Statement

The usage of Air Conditioners is increasing rapidly due to the hot climate. Since the air conditioner is being used highly in most of the houses, the energy that is being wasted by the air conditioner is also high. During the air conditioner usage there are several energy being released by the air conditioner which ends up abandoned. Hereby, the purpose of this project is to recycle the energy which is being wasted. The heat energy which is released by the condenser can be converted into usable electricity by converting the direct current (DC) output from the thermoelectric generator (TEG) and must be able stored in a 12.00 V battery. The main challenge to harvest the energy by TEG will be the small and non-continuous voltage output from the TEG. Hence, the proposed system must be embedded with a battery system to store energy. The second challenge is to ensure the 12.00 V battery to be charged. With that, the voltage input has to be designed properly. A minimum of 13.00 V is required to charge the battery, however, a very high voltage value will end up damaging any of this project's equipment. Therefore, the output voltage from the TEG need to be stepped up and a voltage regulator is required to maintain the desired value. The battery is used as energy storage so that the plug point can be used for three days without the air conditioner being switched on. The output DC voltage from the battery is then converted to a socket outlet using a 1000 W inverter that converts DC to alternating current (AC). By doing so, the consumers get to save their electrical bill, while our country gets to achieve a green environment. Establishing this project will counter all the problems and create a new invention to consume the waste heat energy releases.

### 1.2 Objectives

The objectives of this project are:

1) To investigate the potential energy that able to harvest from the air conditioner system.
2) To design and develop the energy harvest kit to harvest waste energy from air conditioners
3) To examine the performance and effectiveness of energy harvesting for air conditioners

### 1.3 Project Scope

The scope of this project has been set to achieve all the objectives. Firstly, the potential energy which will be chosen to be harvested is thermal energy. Thermal energy is being wasted and abandoned by every air conditioner users, hence it would be the best choice of energy to be harvested. Next is to design and develop the TEG which converts the thermal energy into usable electricity. The connection of TEG will be tested in both series and parallel. The best connection will be implemented in the project. Finally, the performance and effectiveness of the sandwiched TEG are being tested by placing the TEG at two different locations in the condenser of the air conditioner unit. The best location is chosen based on the performance of the voltage produced by the TEG.

## 2. Materials and Methods

Figure 3 depicts the project's progress from beginning to finish. Thermal energy comes from the compressor of an air conditioner. First, the TEG will obtain thermal energy from the compressor's discharge pipe / heat tank. When the TEG's body interacts with heat, current and voltage are produced, which are then stored in the battery for backup power usage during the non-usage of the air conditioner. Next, the battery which is charged is then used for a socket outlet with the help of a 1000 W inverter which converts the DC to AC. The socket outlet can be used for house appliances such as stand fan and many more.

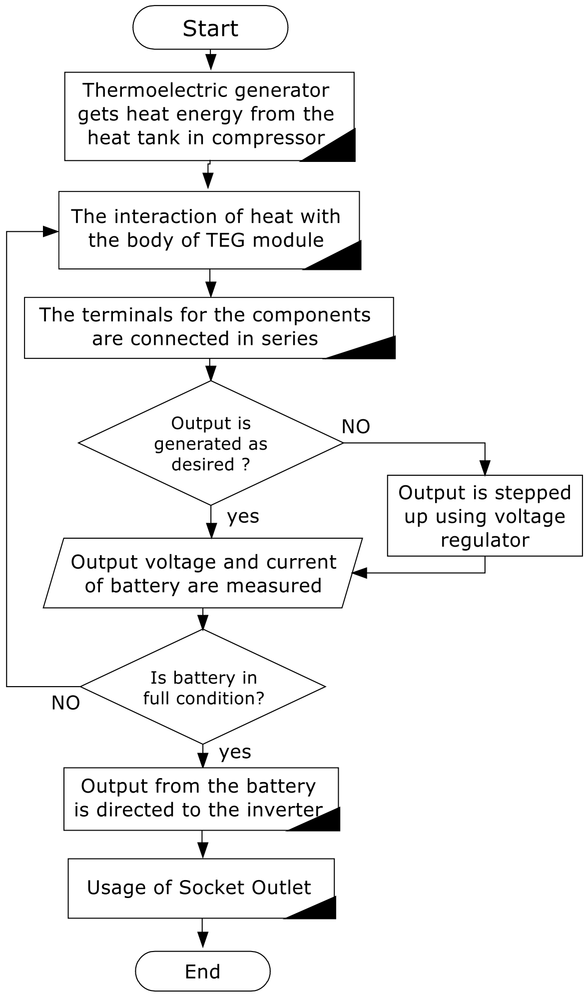


**Figure 3 : Flow chart for Development of Thermal Energy Harvesting from Air Conditioner for Self-Powered Smart Home Appliances**

### 2.1 Process of Thermal Energy Harvesting for Smart Home Appliances

Figure 4 depicts the block diagram for the development of thermal energy harvesting from air conditioners for self-powered smart home appliances using the thermoelectric generator. The thermal energy is being taken from the discharge pipe of the condenser by placing five thermoelectric generators which will be sandwiched with an aluminium plate and attached to the discharge pipe. Then the output voltage produced by the five thermoelectric generator is 3.00 V. The DC will charge the battery by stepping up the voltage using a step up module which steps a minimum of 3.00 V up to 40.00 V. A

12.00 V battery requires at least 13.00 V to be charged. Then the 1000 W inverter plays its part by converting the DC current into AC current for a socket outlet which will be used for the home appliances.

Air-Conditioner's Compressor

Thermoelectric Generator

Step up module

Socket Outlet

1000W Inverter DC to AC

12 V, 7.2AH Battery

**Figure 4 : Block diagram of Thermal Energy Harvesting for Self-Powered Smart Home**

## 2.2 Output produced for the number of TEG

Table 1 depicts the number of TEG used and the generated voltage output produced by different number of TEG which are connected in series.

**Table 1: Voltage produced for the numbers of TEG**

| No. of TEG | Voltage produced (V) |
|---|---|
| 1 | 0.6 |
| 2 | 1.2 |
| 3 | 1.7 |
| 4 | 2.6 |
| 5 | 3.8 |

Based on the table it is clearly proven that five units of TEG are best to be used. As been explained earlier that a minimum of 3.00 V is required to proceed with the project, and the 3.00 V is being obtained by using five units of TEG connected in series. The more the TEG the higher the voltage produced. However, only five units were used in this project because of the placement of TEG can only fit up to five units.

## 2.3 TEG arrangement

Five units of TEG are used to enhance the voltage required for this project's development. Figure 5 shows the TEG is being sandwiched according to the figure. The purpose of the sandwiched condition is to make sure the TEG does not miss place the position and ease the series connection of the TEG. Series connection is being selected for the connections among the TEG as it produces greater resultant voltage and does not overheat easily.

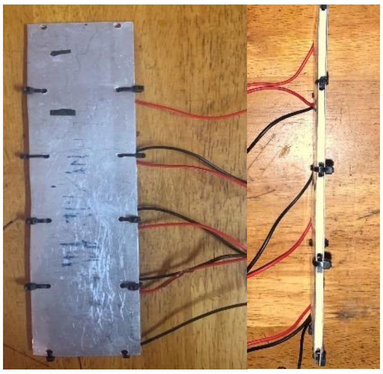

**Figure 5: TEG in sandwiched condition**

## 2.4 Placement of TEG

The methods used to succeed in this project by locating the TEG at two different locations will be discussed in this section. The two locations are proposed, which are located at the discharge pipe of the condenser or the heat tank of the condenser. Figure 6 shows the TEG being located at the discharge pipe and followed by Figure 7 which shows the TEG being located at the heat tank. This placement is tested to determine the perfect location for the TEG to be placed for the development of this project.

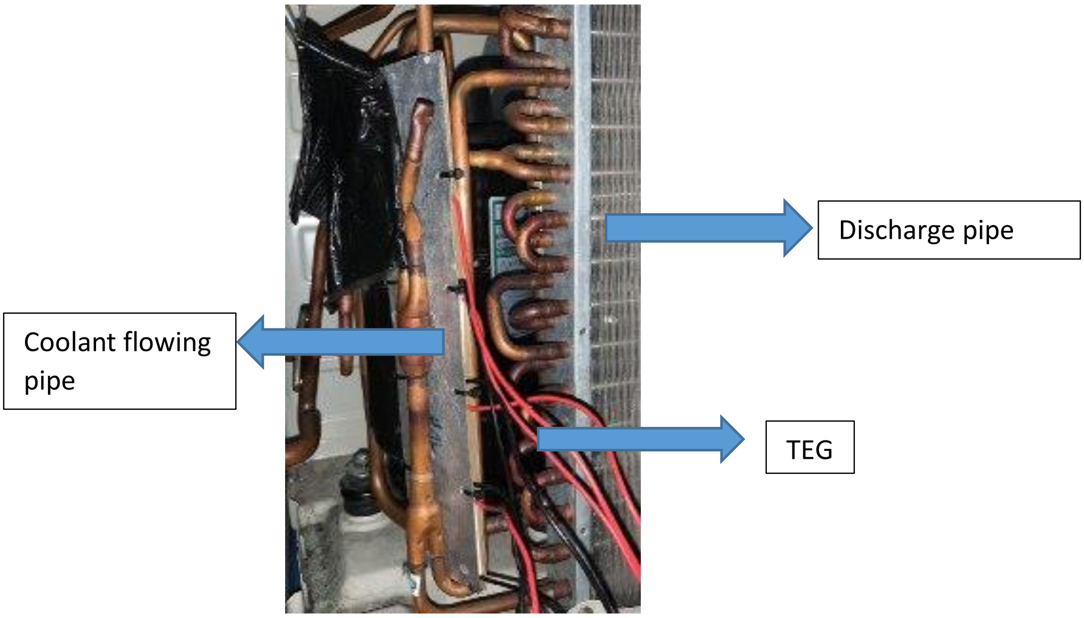


**Figure 6: TEG placed at the discharge pipe**

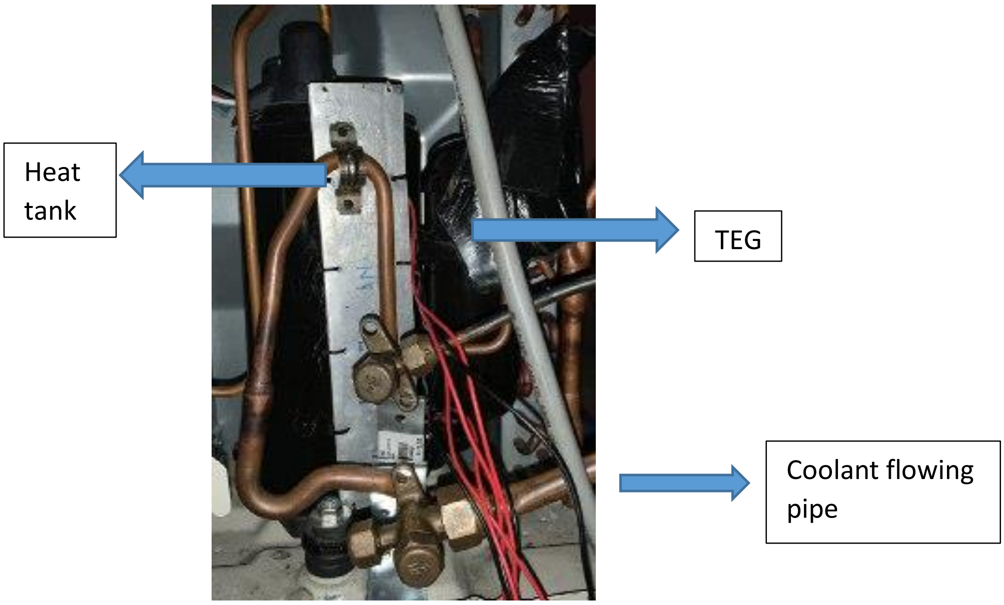


**Figure 7 : TEG placed at the heat tank**

## 3. Result and discussion

The result produced for two different locations will be shown and proved. The reason for the specific placement being chosen will also be discussed in this section.

### 3.1 Complete set up of the proposed development of thermal energy harvesting from air conditioner for self-powered smart home appliances

The project is being set up as shown in Figure 8. A voltage regulator circuit is included to ensure the battery gets a constant and stable voltage while charging. The voltage from the battery is then feed to the inverter which converts the DC output to AC output for the socket outlet used for the home appliances. Figure 9 shows the set up proposed system for the socket outlet application. It consist of step up module which steps the voltage produced by the TEG, LED display that displays the voltage once it is stepped up, 12.00 V 7Ah sealed lead acid battery which stores the energy produced by the TEG, 1000 W inverter which converts the DC output from the battery to AC output for the socket outlet, and finally a voltage regulator to stable the voltage for the battery which consist of resistor with the value of 1 K ohm, 100 micro farad capacitor, IN40007 diode. In this study, the TEG managed to produce a minimum of 2.80 V which is then being stepped up to 13.00 V. The 13.00 V is used to charge the battery which is then used as back up power during the non-usage of the air conditioner.

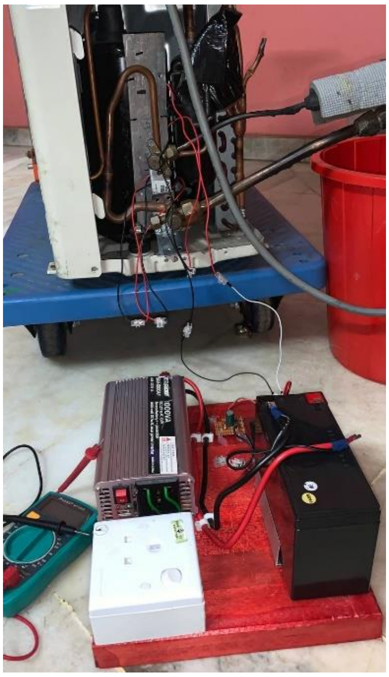

**Figure 8: Complete set up of the project**

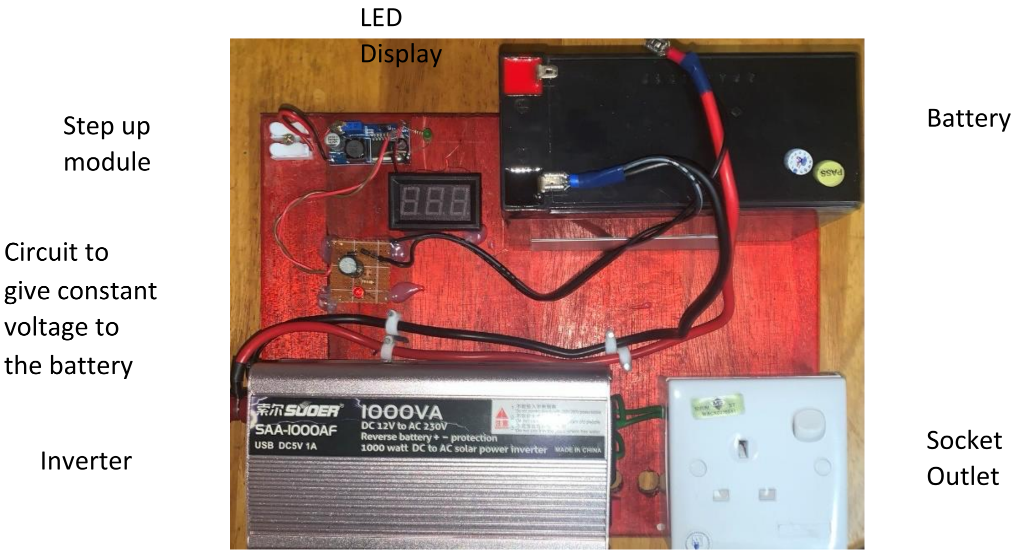


**Figure 9: Complete set up of development of thermal energy harvesting from air conditioner for socket outlet application**

3.2 Data analysis of the TEG being placed at the discharge pipe

In the tests, five TEG of series units are employed. The TEG units were initially tested at the discharge pipe. The results of TEG modules are shown in Table 2. The voltage output of TEG units is 0.27 V with a temperature of 51.3 °C after 5 minutes of air conditioner operation. When the temperature rises, the voltage output produced by TEG units rises with it. The units may produce up to 1.24 V after 30 minutes of operation. Then the output voltage is remained the same after 30 minutes due to the change in temperature in the indoor unit. The data is plotted to analyse as in Figure 10.

**Table 2: Voltage ouput of TEG placed at the discharge pipe**

| Time Taken (Minutes) | Temperature (°C) | Output Voltage (V) |
|---|---|---|
| 5 | 51.3 | 0.27 |
| 10 | 51.8 | 0.39 |
| 15 | 52.2 | 0.47 |
| 20 | 52.4 | 0.68 |
| 25 | 52.8 | 0.92 |
| 30 | 53.0 | 1.24 |
| 35 | 53.0 | 1.23 |
| 40 - 60 | 53.0 | 1.24 |

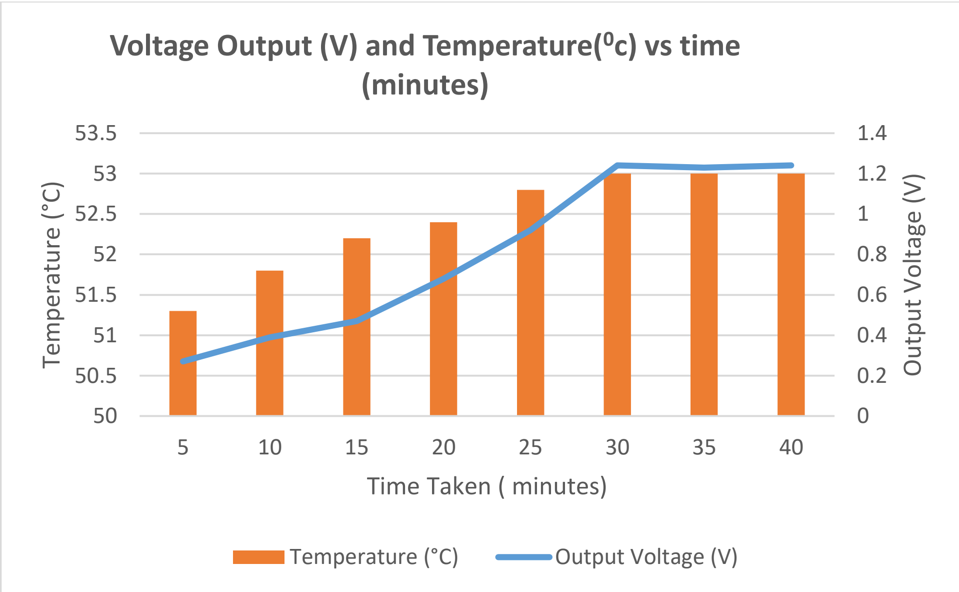


**Figure 10: Graph analysis of voltage output and temperature versus time taken of TEG placed at discharge pipe with the time interval of 5 minutes**

The data has been taken 5 minutes after placing the TEG at the discharge pipe. A 0.27 V is being recorded after the first 5 minutes. The voltage is increased from 0.27 V to 1.24 V after 30 minutes of operation. The maximum voltage obtained is 1.24 V at the time of 30 minutes. The temperature in the discharge pipe is remained constant for the up coming minutes of operation. Hence the voltage output is also remains constant for the operation after 30 minutes.

3.3 Data analysis of the TEG being placed at the heat tank

The new method is identical to the first, except that this time the TEG units are placed at the heat tank. The results of TEG units being placed at the heat tank are shown in Table 3. The output voltage produced by TEG units is 0.64 V with a degree of 52.8 °C after 5 minutes of air-conditioner operations. The test lasted around an hour while the air conditioner was running. With a degree of 68.3 °C, the voltage output is raised to 3.25 V after 30 minutes. The voltage and temperature remain the same for the following minutes. There were no voltage fluctuations or voltage instability throughout this experiment. The data is plotted to analyse as in Figure 11.

**Table 3: Result of TEG modules placed at the heat tank**

| Time Taken (Minutes) | Temperature (°C) | Output Voltage (V) |
|---|---|---|
| 5 | 52.8 | 0.63 |
| 10 | 54.6 | 0.96 |
| 15 | 56.3 | 1.47 |
| 20 | 58.4 | 1.85 |
| 25 | 62.5 | 2.43 |
| 30 | 68.3 | 3.25 |
| 35 | 68.3 | 3.25 |
| 40 - 60 | 68.3 | 3.25 |

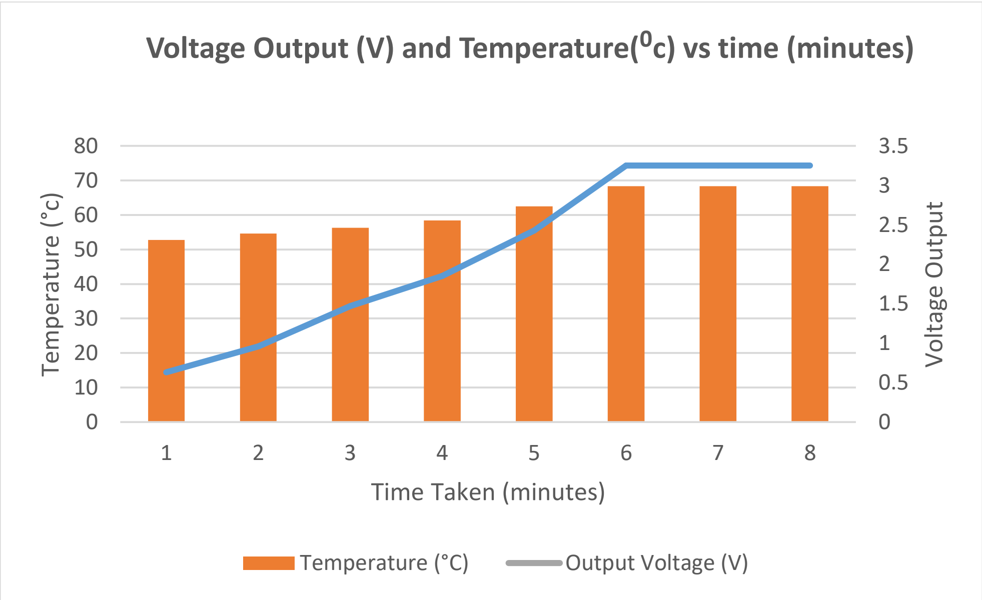


**Figure 11: Graph analysis of voltage output and temperature versus time taken of TEG placed at heat tank with the time interval of 5 minutes**

The first data has been taken by placing the TEG at the heat tank after 5 minutes of operation, a 0.63 V is recorded. The voltage is increased from 0.63 V to 3.25 V after 30 minutes of operation. The maximum voltage obtained is 3.25 V at the time of 30 minutes after the operation. The temperature in the heat tank is remained constant which is 68.3 °C for the up-coming minutes of operation. Hence the voltage output also remains constant for the operation after 30 minutes

### 3.4 Data comparison and analysis for different location placement of TEG

The data collected from both locations have been recorded and analysis will be conducted to choose the best location for the TEG placement. Comparison for placement is shown in Figure 12.

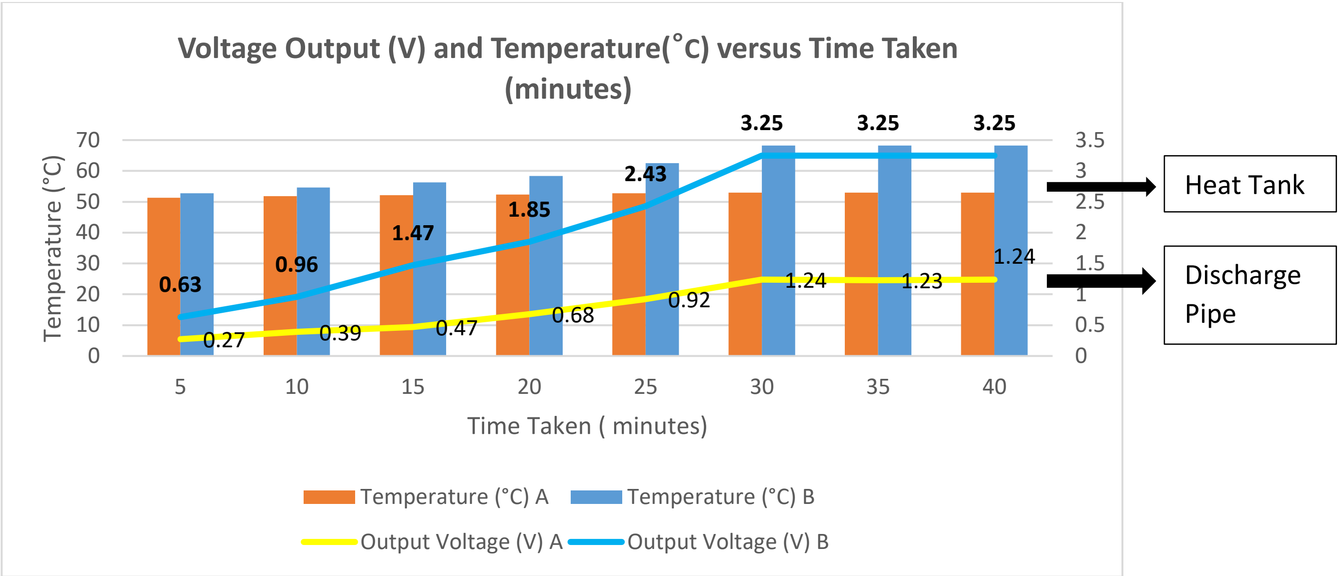


**Figure 12: Comparison of graph analysis of voltage output and temperature versus time taken of TEG placed at discharge pipe and heat tank with the time interval of 5 minutes**

The data clearly shows that the TEG being placed at the heat tank produces more voltage which is 3.25 V after 30 minutes of operation compared to the TEG placed at the discharge pipe which could only produce 1.20 V after 30 minutes of operation. These changes took place due to the difference in temperature of the heat tank and discharge pipe. Hence the TEG placed at the heat tank is being selected to proceed with the development of this project.

3.5 Operation of the Socket outlet application

TEG managed to produce a minimum of 2.80 V which is then being stepped up to 13.00 V. The 13.00 V is used to charge the battery and used as back up power during the non-usage of the air conditioner. A voltage regulator is included to ensure the battery gets a constant and stable voltage while charging. The voltage from the battery is then feed to the inverter to convert the DC output to AC output for the socket outlet used for the home appliances. Figure 13 shows the usage of the socket outlet by the development of thermal energy harvesting from the air conditioner for smart home appliances. The stepped voltage displayed at the led display is 13.50 V.


**Figure 13: Complete set up of development of thermal energy harvesting from air conditioner for self-powered smart home appliances**

## 4. Conclusion

The three objectives of this project are being achieved by choosing the best energy to be harvested which will be the thermal energy. Next is TEG is being selected which can generate electricity with the help of heat and cold. Five TEG is being sandwiched to ensure more voltage is produced. Finally, the effectiveness is being tested by placing the TEG in two different locations to ensure which placement produces more voltage. From the result a conclusion can be made that heat tank placement is the best choice for this project based on the 3.25 V produced by the TEG. During the testing stage, the performances and efficiency are also determined by making the right choice of amount and placement to be used. Because of its characteristics, which are utilised in providing small-scale applications for one unit of thermoelectric generator, choosing the amount of thermoelectric generator to be used is critical. Five TEG are used in this project which gives an output voltage of 3.25 V compared to the lesser unit which didn't managed to even reach 3.00 V. The thermoelectric generator may be utilised to charge the battery, according to the findings. By completing this project, it will provide a new idea of power generation based on waste heat energy from the air conditioner, which will be beneficial to consumers by lowering their existing utility bills.

**Acknowledgement**

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