KEMENTERIAN PENDIDIKAN TINGGI

JOJAPS
eISSN 2504-8457

POLITEKNIK MALAYSIA
PORT DICKSON

Journal Online Jaringan Pengajian Seni Bina (JOJAPS)

# TURNING FOOD WASTE INTO ENERGY – PROTOTYPE OF BIOGAS GENERATOR FOR HOUSEHOLD

Tham Sook Chan[a]*

[a]*Department of Mechanical Engineering, Port Dickson Polytechnic, 71050, Port Dickson, Negeri Sembilan, Malaysia.*

**Abstract**

When there is a human, there always can find waste around. Per capita generation of the waste has been increasing steadily due to population growth, changing socio-economic characteristics and urbanization, and varies from 500g to 800g. During decomposition, these biodegradable materials mostly food waste release carbon dioxide, methane, ammonia, and hydrogen sulphide into the environment thereby contributes to air pollution and odour pollution. The gases that are released can be captured for the economic utility and as well as to save the environment. This paper will present the feasibility study on prototype of biogas generator from food waste, by using TEG Peltier plate in converting heat transfer to electrical energy. The objectives of this paper are two-fold; firstly, to determine whether food wastes from household can produce methane gas (biogas) that can generate heat and electricity and secondly to provide fertilizer by using this household food waste. The gas production rate (G) for the available kitchen waste, working with 20kg/day was found to be 6 cubic metres/day. The higher the wastes, with the more difference of the temperature, the higher voltage may produce, and thus, the higher the amount of methane gas produced. After the biogas production process is completed, organic fertilizers can be made from the slurry generated which may have obtained from exhaust outlet. The active slurry volume in the digester is directly related to the hydraulic retention time (HRT). So active slurry volume for the kitchen waste, with HRT in 30 days, is found to be 1.2 cubic metres. The finding and results are well discussed then. It shows the results still need more study on future work and broad areas to take into consideration.

***Key-word:*** *Food waste, Biogas generator, Renewable energy, TEG Peltier plate, Heat transfer*

## 1. Introduction

Food waste is identified to be a huge issue globally, and is particularly serious in developed countries. For examples, in the United States, food waste and losses at the retail and consumer levels have amounted to 188 kg per capita per year, or an overall value of $165.6 billion. If look at the Europe and the North America, the food waste was estimated as high as 280 – 300 kg per capita per year (Garrone, Melacini, & Perego, 2014). In Southeast Asia region, it is estimated that 33% of food is wasted (Yang et al., 2016). It was reported that in average a household in Malaysia thrown away around 0.5-0.8kg uneaten food per day (Chien Bong et al., 2016). This problem is expected to increase in a few years while corresponding to economic development, population growth, and urbanization as Malaysia's population is expected to reach 33.4 million by year 2020 and 37.4 million by year 2030.

The waste generated has increased from Malaysia in response to population growth from year to year (Chua et al, 2019). The Municipal Solid Waste (MSW) generation is expected to increase by 20% from 2018 to 2026 as show in Figure 1. According to 2016, over 32,939 tonnes of waste is produced each day in Malaysia. However, this amount is expected to rise and near to 41,035 tonnes by the year 2026. Typically, the highest content

* Tham Sook Chan. Tel.: +60125613570; Fax: 066622026
*E-mail address: sookchan@polipd.edu.my*

of the Malaysia household MSW composition as shown in Figure 2 (A. Fazeli et al, 2016) is food waste (44.5%) followed by plastic (13.2%), paper (8.5%), diapers (12.1%), garden waste (5.8%), glass (3.3%), textiles (3.1%), metal (2.7%), rubber (1.8%), tetra Pak (1.6%), wood + peel/husk (1.4%), Household Hazardous waste (1.3%), leather (0.4%) and others (0.5%). Due to the population growth, economic growth and business activities, food waste in Malaysia especially has increased drastically from 2011 and onward. On the hands, Malaysia is not in conjunction with the effective and systematic management of solid waste treatment, and this may impact the environment and human health if waste management or waste treatment does not plan and work accordingly. Thus, there need a proper solution to handling this huge problem. According to Chua et al. (2019), the implementing 'Reduce', 'Reuse' and 'Recycle' ('3 R's') is still lack of interest in attention by Malaysian. By the way, the recycling rate has increased slowly to 10% during 3R implementation. Now is the right timing for Malaysia start its road to look forward in its sustainable energy, by officially established many parties to the development and promotion of RE and cutting down on the carbon emissions.

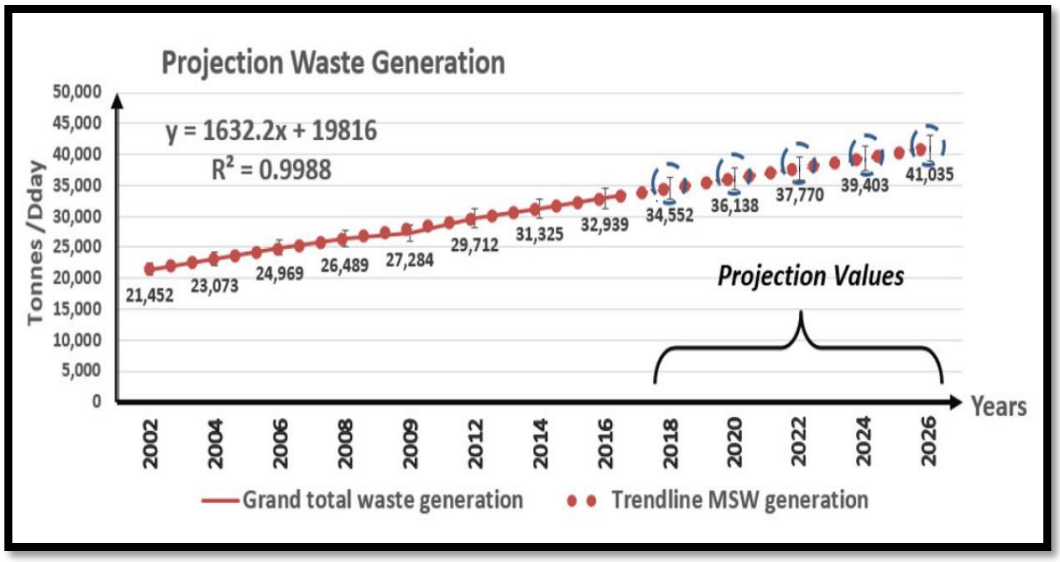



**Figure 1** Projection Daily waste generation in Malaysia (Chua et al, 2019)

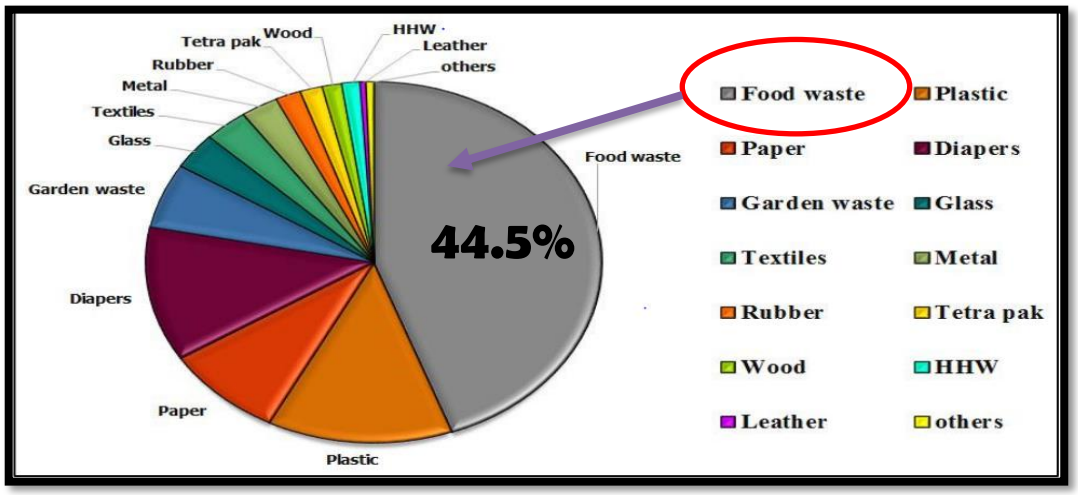



**Figure 2** Typical household MSW composition in Malaysia (A. Fazeli et al, 2016)

From the issue found in human routine, a project is figure out to solve the related by reuse the waste to produce electricity. It is called food waste biogas generator which the food waste will rot and produce biogas. The gas will convert to heat energy, and heat the water then transfer to TEC and produce electricity. After finishing the process of producing electricity, the food waste may become fertilizer. It uses reuse concept. This project may lead a lesson, is to remember always no food waste. The less food waste, the less pollution creates.

## 2. Literature Review

In an age of worrying climate change and looming fossil energy decline, the benefits of biogas are obvious nowadays. It is a renewable energy source with zero net greenhouse emissions, home with a zero-emissions alternative to paying for fossil gas. And yet its potential has largely gone untapped, at least in the developed world (Samuel Alexander, 2018). Based on many research done, it can be contended that home-produced biogas is an extremely promising technology whose time has come. In Malaysia, Penang state had started its first biogas pilot plant on 23rd June 2019 as shown in Figure 3, a 'feasibility study 'of food waste being converted to renewable energy (The Star, 24 June 2019). This state is adopting the technology from the Danish company, which has the biggest plant of this nature in the world, in order to cater issue on waste management. The Penang state government welcome this solution and hope it could reduce the amount of waste sent to the Pulau Burung landfill, which only has a remaining 30-year lifespan, in the way it has to be addressed efficiently and effectively.


**Figure 3** Chief Minister Chow Kon Yeow pouring the food waste into the food shredder.

What biogas is about? Biogas is produced when organic matter biodegrades under anaerobic conditions (that is, in the absence of oxygen). This process produces a mixture of gases – primarily methane ($CH_4$), some carbon dioxide ($CO_2$) and small portions of other gases such as hydrogen sulfide, as show in Figure 4. When the biogas is filtered to remove the hydrogen sulphide, the resulting mixture can be burned as an energy source for cooking, lighting, or heating water or space. When compressed it can be used as fuel for vehicles. On a commercial scale biogas can be used to generate electricity or even refined and fed into the gas grid. The types of organic matter used to produce biogas include food waste, animal manure and agricultural by-products. Some commercial systems use sewage to produce and capture biogas (Samuel Alexander, 2018).

Biogas generation serves three important functions: waste removal, environmental management, and energy production. The first and most direct use of biogas is for heating and domestic purposes. Biogas is an excellent fuel with various application. Biogas that is purified and enriched in methane can be used for household applications, automobile fuel (liquefied), or electricity generation. The biogas is mostly utilized as a combined heat and power (CHP) application in the overall world; and apart from it, it can be used in three sides such as fuels for cars, steam generation, and electric power.

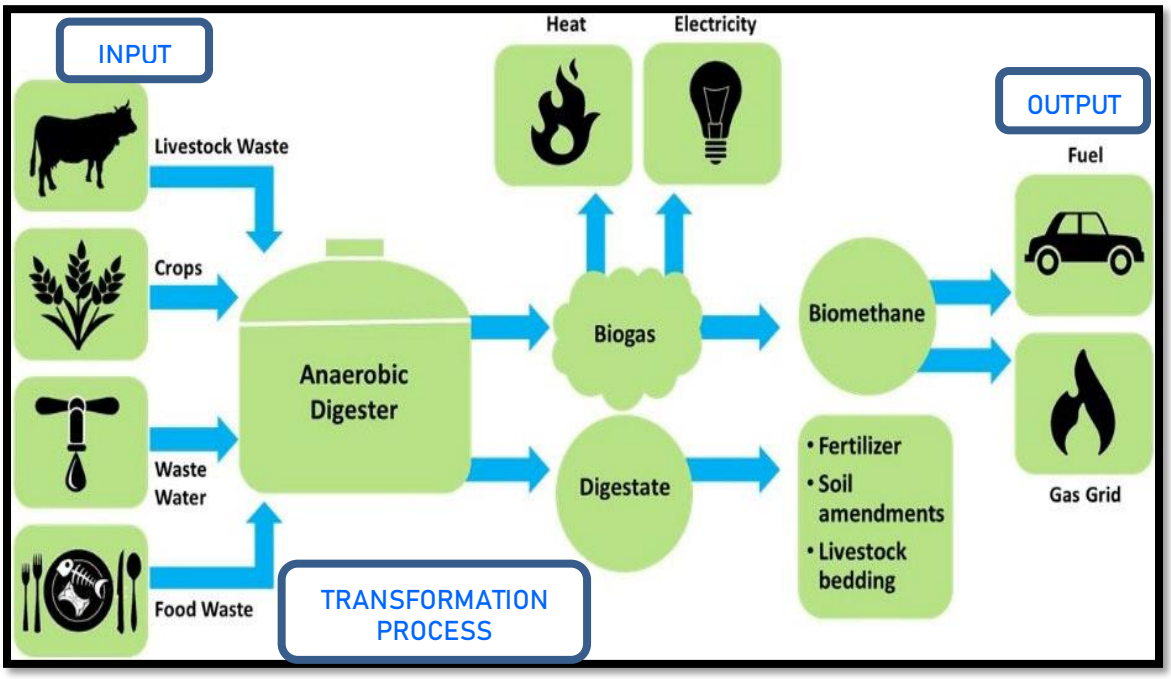



**Figure 4** Anaerobic digestion process (https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy)

There is a number of research shows efficient generation of electricity from Thermoelectric generator (TEG), by using the principle of see back effect, which is the phenomenon a temperature difference between two dissimilar semiconductor produces a voltage difference between two substances. The higher temperature difference, the higher voltage is produces. So, what is TEG about?

A Thermoelectric generator (TEG), also called as see beck generator, is a solid state device that convert heat (Temperature difference) directly into electric energy through a phenomenon called the see beck effect (A form a thermoelectric effect). Thermoelectric generator function like heat engine but are less bulky and have no moving part however; TEGs are typically more expensive and less efficient. Thermoelectric generator could be used in power plant in order to convert waste heat into additional electric power and in automobiles as automotive thermoelectric generator to increase fuel efficiency.

The TEG structure as show in Figure 5 is sandwiched with the thermoelectric material which is then sandwiched by the heat exchanger plates at their ends respectively. The two heat exchangers remain at different temperatures, one at high temperature and the other at lower temperature and called the hot side and cold side. A thermally insulated layer is present between metal heat exchanger and material of a TEG. The p type and n type materials are connected by the metal electrically. The hotter side derives the electrons in n type leg towards the cold side which pass through the metallic connection and then passes into the p type leg, hence develops current. Larger the temperature difference between cold side and hot side, larger value of emf will produce (Mohd.Quasim Khan et al., 2018).

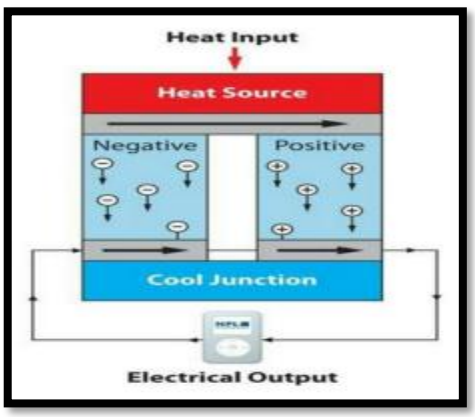



**Figure 5** Layout of a TEG.

## 3. Problem Statement

Human tends to lazy to do everything include lazy to throw food waste into trash can, but the best place to throw, people will prefer to throw it into sink at kitchen. Habit to throw food waste at sink, may block water flow to the drainage system because the food waste getting stuck in the piping system, and it cause another expenses for this plumbing complication in clearing the water pipe. Besides that, some vermin such as cockroaches, mice and ant will be attracted and get into house. In this case, there is high possibility to bring various of diseases to human, such as food poison. As an example, food poison case in Tapah is shown in Figure 6. A total of 62 students and a teacher at Sekolah Menengah Sains Tapah suffered food poisoning after eating at the boarding school's dining hall on April 2, 2016 (Bernama, 06 April 2016). This is danger to human being and it must be prevented from occurring in any public area, especially education institution.

**Figure 6** Food poison case at Sekolah Menengah Sains Tapah in Tapah (*Bernama on 12 April 2016*)

Other than this, environment and water pollution are a seriocomic problem face by human. Waste food will become rubbish, then throw to garbage car and send to landfill. When trash is start rotting and it will issue bad smell. When food waste is accumulating from day to day, it may affect the surrounding environment, from the bad smell produce. The rubbish will be more and more and it will cause certain pollution. The rubbish rot together in land fill and the bad smell will diffuse to environment, so it will cause pollution. Water pollution will happen too. As the rubbish rot and it will produce water that will run to the river or beach and cause water pollution then. Example, situation at Krubong Melaka as shown in Figure 7. In this situation, an idea for reducing food waste have been discovered to solve the problem.

**Figure 7** Krubong Melaka happen landfill food waste trash (*https://www.thestar.com.my/news/community/2014/09/26/a-need-of-an-incinerator-ecofriendly-facility-in-state-would-not-affect-green-technology-status/* )

## 4. Objective

The objectives to address the problem statement that has been found are as follows:

i. To build up a prototype of biogas generator for electric appliance in small scale from biogas that produce from food waste.
ii. To provide fertilizer that contain more nutrient than inorganic by using household food waste that suitable for gardening and agriculture purpose.

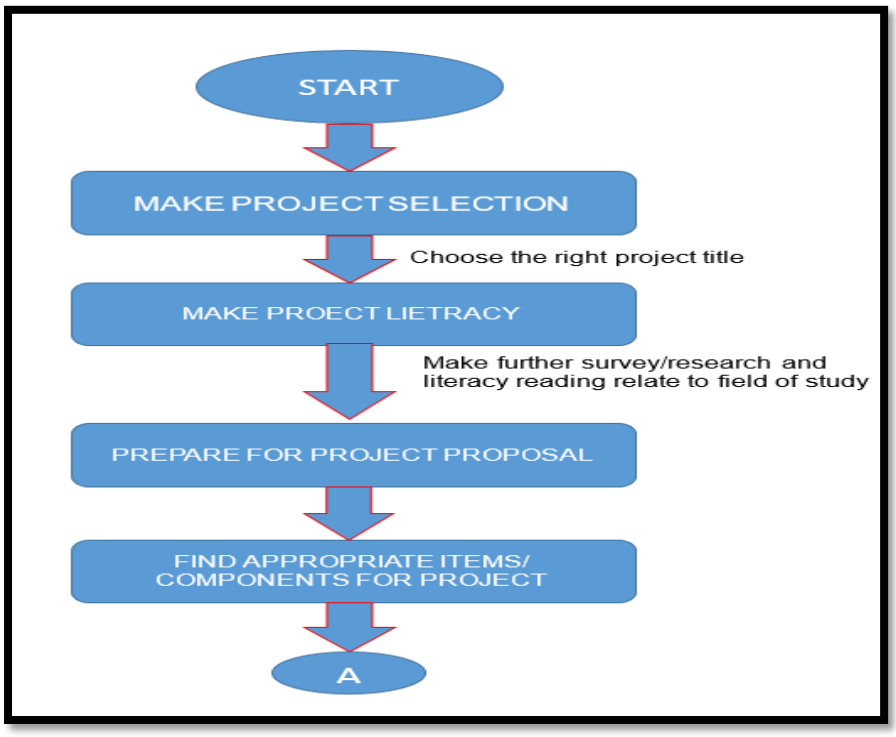
## 5. Scope of Study

Scope of study is required in build up this prototype of biogas generator and the limitation of study are as following:

i. The limitation of container that a tank can fill with 5kg of food waste.
ii. Can use only for food waste except animal bone because the food waste will ferment and produce biogas, but animal bone difficult to ferment and it is a toughness process.
iii. Produce by biogas digester container which is in credibly flammable. The energy release from biogas can be used in a gas engine to convert the energy in the gas into electricity.
iv. Can use for household, gardening and catering because the most food waste, the more biogas can produce and the food waste can use as fertilizer to provide nutrition for gardening.

## 6. Methodology

Methodology is one of the most important parts of the study and is described in detail. It covers the procedures, methods and approaches to achieve the objectives of the study. Proper methodology will make the study carried out more systematic and the flow of the study is focused on the direction for achieve the objectives of the study. This part describes the research methodology used in the study. Research methodology and strategies were compiled to obtain information and data to achieve the objectives of the study. Data Collection Methods is applied for the production of prototype of biogas generator for household, by doing data collection in daily observation on all parameter of biogas production in 30 days. This study performs data collection according to the flow chart as show in Figure 8.



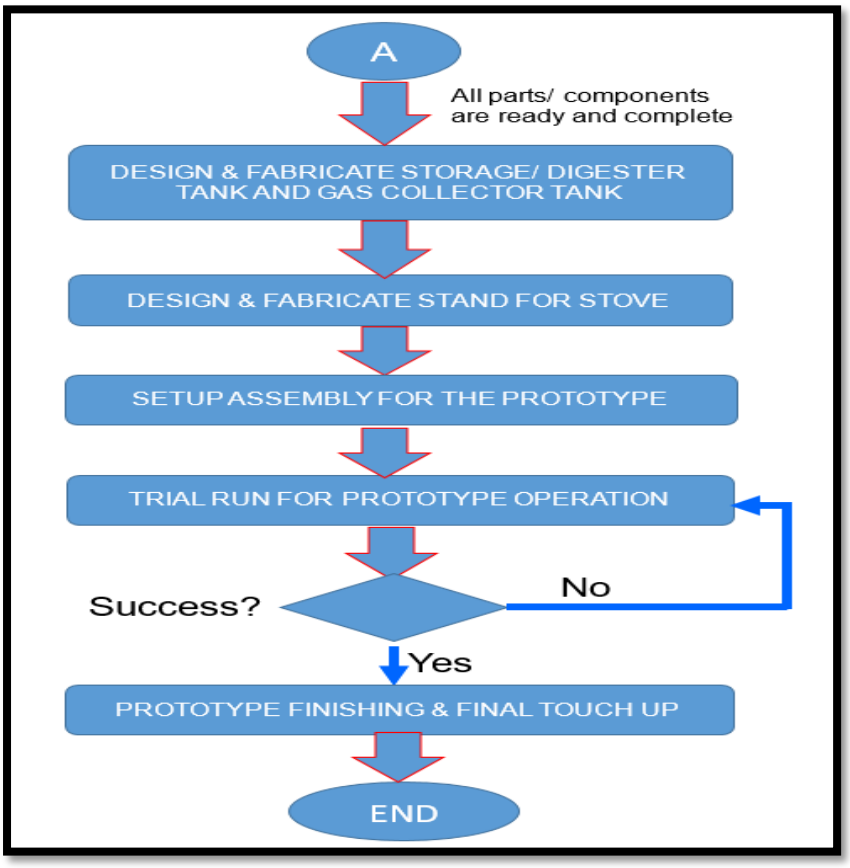



**Figure 8** Project process flow chart

## 7. Results and Analysis

The data was gathered when the eight (8) TEG Peltier plates were heated up with the fire produced by biogas. The experiment involves 5 trials which were checked every 10 seconds. Time was measured through the use of a stopwatch which was stopped after each trial. A thermometer was used to measure the heat of an aluminium plate which was placed above the fire produced by the gas. Voltage was measured through the use of digital voltmeter that is connected in the Peltier plates which convert heat energy of the fire into electricity. The researchers used these instruments to efficiently gather the data in testing. The testing was executed after 31 days of decomposition of organic materials which was sealed and undergone anaerobic respiration. The researchers prepared all the instruments needed and made sure that all devices were working properly for the testing.

**Table 1** Data gathered during the experimental phase.

| Time (seconds) | Temperature (°C) Hot | Temperature (°C) Cold | Voltage Per TEG Peltier Plate (V) |
|---|---|---|---|
| 10 | 52 | 5 | 0.69 |
| 20 | 77 | 5 | 0.71 |
| 30 | 97 | 5 | 0.88 |
| 40 | 106 | 5 | 1.10 |
| 50 | 132 | 5 | 1.39 |

Table 1 shows the voltage produced by the Peltier plates and the temperature affecting it with the increasing time. Celsius is the unit used in the measurement of temperature. The data gathered by the researchers shows the direct relation of the temperature that comes from the biogas, the cooling system, and the voltage that is being produced. The conversion of heat energy of the eight (8) Peltier plates, working simultaneously, converted

almost 5.6 volts and is able to charge an Android phone. However, the amount of biogas that the researchers used in the testing only lasted for about one (1) minute and started to fade in the succeeding minutes, the biogas, as well as the voltage, slowly decreased.

According to Ferrotec's Thermoelectric Technical Reference Guide, for any thermoelectric generator design it is always desirable to maximize the applied temperature differential in order to minimize the total number of modules in the system. This situation can be clearly seen in Figure 9. Module requirements for a typical 12-volt, 1-ampere power generator, as an example, are plotted at several fixed values of Th based on the use of 127-couple 6-ampere TE modules. From this graph, it is evident that a very large number of modules is needed when the cold side temperature (Tc) is high and the temperature differential, therefore, is small. Performance of the cold-side heat sink is of the utmost importance and its thermal resistance must be extremely low. In many cases, cold-side heat sink design will prove to be the most challenging engineering problem.

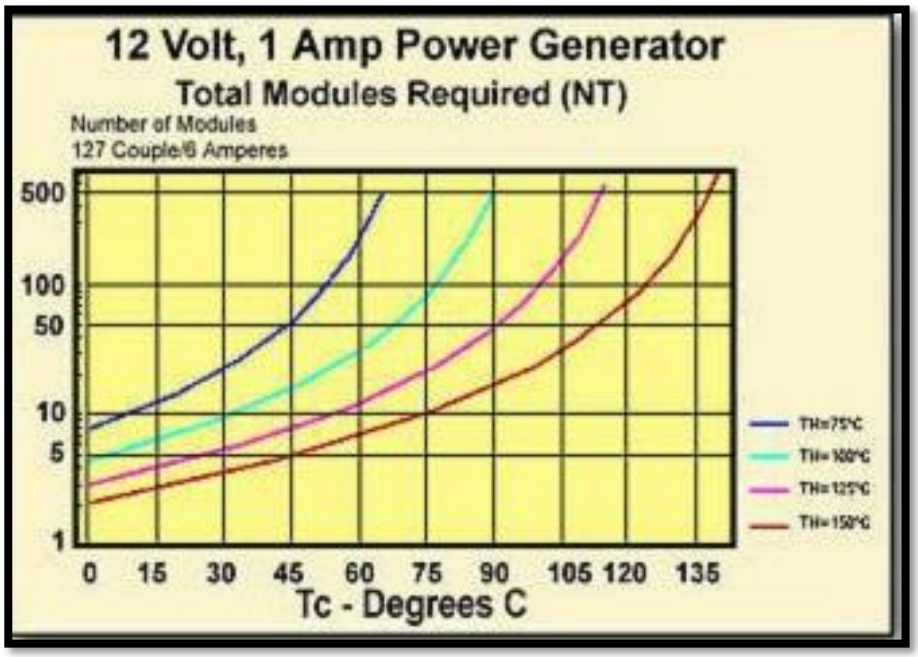



**Figure 9** Graph of total modules required

## 8. Conclusion

After making the analysis, there are some weaknesses in the innovation of this prototype. Few main factors to be considered in biogas production, and more study work have to focus in future study.

i. Sublayer composition;
ii. Temperature inside the digester;
iii. Retention time;
iv. Working pressure of the digester;
v. Fermentation medium pH;
vi. Volatile fatty acids (VFA).

Anaerobic digestion is an established technology, used to treat a wide variety of organic wastes. It is one of several biological processes that deliver economic and environmental benefits (i.e., producing bioenergy and/or biochemical while treating the organic fraction of waste). The anaerobic digestion process is complex—it includes various physical and biochemical reactions. The stability of the anaerobic digestion process is affected by many factors (e.g., the conditions inside and surrounding the reactor, the reactor's design, the operational parameters, etc.). In order to maintain a stable, efficient, and sustainable biogas production, the operational parameters should be determined and controlled

After gathering the data for 31 days, it proves that it could produce enough amount of electricity that could charge an android phone in a limited time, thus researchers still conclude that the product is indeed effective and has a big potential in the world of renewable resources. It may not be easy to use like other renewable resources but still, it is definitely cheaper and environmentally friendly. Overall, the innovation this small biogas generator prototype can produce fire, from food waste by using heat transfer to electricity generation by using TEG Peltier plate. Concept of TEG Peltier plate is heat and cold side to generate electricity. The more difference of the temperature, the higher voltage may produce. Food waste may produce biogas and thus produce electricity. No bad smell will be produced and effect the environment then. It is time to educate Malaysian public aware of 3R concept - practice toward green environment for household user by using biogas.

**References**

Alireza Fazeli, Farzaneh Bakhtvar, Leila Jahanshaloo, Nor Azwadi Che Sidik, & Ali Esfandyari Bayat. (2016). "Malaysia's stand on municipal solid waste conversion to energy: A review". Renewable and Sustainable Energy Reviews. 58 (May 2016), pp1007–1016.

A need of an incinerator. [September 26] The Star Online [2014] Retrieved from https://www.thestar.com.my/news/community/2014/09/26/a-need-of-an-incinerator-ecofriendly-facility-in-state-would-not-affect-green-technology-status/ [Accessed 01 October 2020]

Chien Bong, C.P., Ho, W.S., Hashim, H., Lim, J.S., Ho, C. S., Peng Tan, W.S., & Lee, C. T. (2016). "Review on the renewable energy and solid waste management policies towards biogas development in Malaysia". Renewable and Sustainable Energy Reviews. 70 (April 2017), pp988-998. https://doi.org/10.1016/j.rser.2016.12.004

Chua, H. S., Bashir, M. J. K., Tan, K. T. & Hung Soon Chua (2019). "A sustainable pyrolysis technology for the treatment of municipal solid waste in Malaysia". AIP Conference Proceedings 2124, 020016. https://doi.org/10.1063/1.5117076

Garrone, P., Melacini, M., Perego, A. (2014). "Opening the Black Box of Food Waste Reduction". Journal of Food Policy. 46 (June 2014), pp 129 – 139. http://doi.org/10.1016/j.foodpol.2014.03.014

Malaysia is overflowing with waste and we're running out of options [July 16] The Star online [2019] Retrieved from https://www.thestar.com.my/lifestyle/living/2019/07/16/plastic-waste-landfills [Accessed 01 October 2020]

Mohd.Quasim Khan, Malarmannan S., Manikandaraja G. (2018) "Power generation from waste heat of vehicle exhaust using thermo electric generator: A review". 2nd International conference on Advances in Mechanical Engineering (ICAME 2018). IOP Conf. Series: Materials Science and Engineering 402 (2018) 012174.

Penang to salvage food waste [June 24] The Star online [2019] Retrieved from https://www.thestar.com.my/news/nation/2019/06/24/penang-to-salvage-food-waste/ [Accessed 01 October 2020]

Tapah food poisoning: Number of victims rises to 63 [April 06] Bernama [2016] Retrieved from https://www.astroawani.com/berita-malaysia/tapah-food-poisoning-number-victims-rises-63-101403 [Accessed 01 October 2020]

Samuel Alexander (2018). "Home biogas: turning food waste into renewable energy" Retrieved from https://theconversation.com/home-biogas-turning-food-waste-into-renewable-energy-89920 [Accessed 01 October 2020]

Sara Tanigawa. (2017). Fact Sheet Biogas: Converting Waste to Energy. Environmental and Energy Study Institute (EESI). Retrieved from https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy [Accessed 01 October 2020]

Unwashed eggs for roti jala cause of food poisoning at Tapah school [April 12] Bernama [2016] Retrieved from https://www.astroawani.com/berita-malaysia/unwashed-eggs-roti-jala-cause-food-poisoning-tapah-school-102031 [Accessed 01 October 2020]

Yang, Z., Koh, S. K., Ng, W.C., Lim, R. C. J., Tan, H.T.W., Tong, Y.W., …Wang, C.-H. (2016). "Potential application of gasification to recycle food waste and rehabilitate acidic soil from secondary forests on degraded lain in Southeast Asia". Journal of Environmental Management, 172, pp 40 - 48. Volume 172 (1 May 2016). https://doi.org/10.1016/j.jenvman.2016.02.020

*https://www.buletinmutiara.com/penangs-first-food-waste-to-energy-biogas-pilot-plant-launched/* [Accessed 01 October 2020]

*https://thermal.ferrotec.com/technology/thermoelectric-reference-guide/thermalref13/* [Accessed 01 October 2020]