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# The use of thermo electric generator to utilize the waste heat from the biomass stove into electricity

To cite this article: B H Tambunan *et al* 2022 *J. Phys.: Conf. Ser.* **2193** 012045

# The use of thermo electric generator to utilize the waste heat from the biomass stove into electricity

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**Abstract.** Indonesia has a huge potential for biomass energy resources. In 2013, the estimated potential of forest biomass in Indonesia for bioenergy was 132 PJ, 50.4% from harvest residues and 49.6% from wood processing residues. Until now, the technology of burning biomass using a stove continues to develop. Biomass stoves are designed, modified and tested to get maximum performance, at least approaching the performance of LPG-fueled stoves. Several studies concluded that about 14.66% of the total heat loss is on the walls of the biomass stove. The purpose of this study was to investigate whether the waste heat in the wall of a biomass stove can be used to generate electricity. Many researchers have studied the heat loss on the walls of the biomass stove, this heat loss can reduce the thermal efficiency of the stove and can cause the stove user to feel uncomfortable. Based on the Seebeck effect method where the temperature difference can be converted into electricity. If there is a temperature difference between the two sides of the thermoelectric, electricity will arise. This principle is used by thermoelectric generators. To maximize the temperature difference, the cold side of the Thermoelectric Generator (TEG) needs a cooling system. In this study, the TEG was attached to the wall of the biomass stove, then the voltage generated by the TEG was measured for each type of biomass fuel. the highest average voltage produced by wood chips, followed by candlenut shells, corn cobs and coconut shells. This is unique, although the calorific value of coconut shells (19,5 MJ/kg) is higher than hard wood (18,8 MJ/kg) and corn cobs (5.32 MJ/Nm$^3$), but the highest average voltage is produced by wood 1.30 volts, then 1.12 volts of candlenut shells, 1.08 volts of corn cobs, and 0.79 volts of coconut shells.

## 1. Introduction

Indonesia has abundant forest biomass resources, which should not be considered as a resource with low economic value. This forest biomass resource can be converted into bioenergy through various technologies and become one of the sources of energy mix in Indonesia [1]. According to Simangunsong et al. (2017) the estimated total potential of forest biomass in Indonesia for bioenergy in 2013 was 132 PJ. Around 50.4% came from harvesting residue and 49.6% from wood processing residue [2]. In 2011, fuelwood consumption was approximately 42 million m$^3$ and is expected to increase to 55 million m$^3$ by 2030 [3]. Biomass is usually burned directly to obtain heat energy, but this greatly affects the human environment in the long term [4]. Carbon monoxide (CO) as a result of the combustion reaction will be released into the atmosphere and can interfere with the human respiratory system. CO is a type of pollutant resulting from the combustion of fuel [5].

Access to standard forms of energy in cooking and lighting has become a serious concern among the vast majority of people living in the world's rural areas [6]. More than 2 billion people, mostly concentrated in rural areas of India and sub-Saharan Africa, use firewood inefficiently (thermal efficiency <8–10%) as fuel for traditional cooking stoves. About 15% of the energy from the fuel is stored in the stove body as waste heat [7]. Until now, the technology of burning biomass using a stove continues to develop [8]. Combustion stoves are designed, modified and tested to get the expected performance at least close to the performance of stoves that use LPG or kerosene as fuel[9]. However, because the combustion reaction is not stoichiometric, where excess air is supplied to the stove, it will produce a high temperature (950 –1100) 0C. High temperatures will trigger a reaction for the formation of NOx pollutants, where nitrogen in the air reacts with oxygen to form carbon monoxide (CO) or carbon dioxide (CO2). Besides causing pollution, fine particles, unburnt carbon will also be formed and released into the free air with the combustion gases [10]. The use of biomass cook stoves is widespread in the rural communities of developing countries. It is important to improve the efficiency of these stoves in order to reduce the global warming contribution [11]. Recovering waste heat could be considered as a complementary solution with renewable systems [12]. The essential problem with thermal energy is that thermal energy have to be used without delay and without delay after it's generated [13].
Many researchers have studied the amount of heat that is wasted from the walls of the biomass stove, this heat loss in addition to reducing the thermal efficiency of the stove can also cause stove users to feel uncomfortable. Biomass stove midification proved to be most effective as it not only preserved the heating functionality of the stove but also improved the stove's efficiency by about 20% while generating 1.113 kW of electricity [14].

If the wasted heat from stoves can be used to generate electricity, at least two benefits will be obtained, namely: (1). The use of the stove is safer and more comfortable, because there is no heat interference from the stove wall, (2) The electricity generated from the stove wall heat can be used either to charge cellphones or as a blower driver to supply air into the stove to improve stove performance.
In developing countries, including Indonesia, most of the population lives in rural areas, some of these villages are remote areas where it is still difficult to get gas or oil fuel, some even have no electricity. In rural areas, there is a lot of biomass in the form of agricultural waste, so they can use this stove for daily cooking purposes and for home industries.

Gasification of wood (or other biomass) offers the possibility of cleaner, better controlled gas cooking for developing countries [15]. It has been proven that the existing biomass cook stoves can be improved to reduce emission of toxic gasses and harmful particulates based on the principle of gasification [16]. According to Ram et al. (2020) In recent years, investigations into the use of gaseous products from biomass gasification in internal combustion engines have been increasing. Internal combustion engines with the type of spark (spark-iqnition engines) are the most studied because the engine can be tested without changing the dimensions of the engine. In areas where electricity is difficult to reach, biomass-based power generation systems are the main choice given the availability of easily available biomass. Gas products can be used as fuel for internal combustion engines which are connected directly to generators to generate electricity [17]. In the international development program on increasing the energy supply for cooking in remote areas, the biomass gasifier cooking stove has an outstanding place. The type and size of the fuel plays an important role in the performance of the stove [16].

Journal of Physics: Conference Series **2193** (2022) 012045 doi:10.1088/1742-6596/2193/1/012045

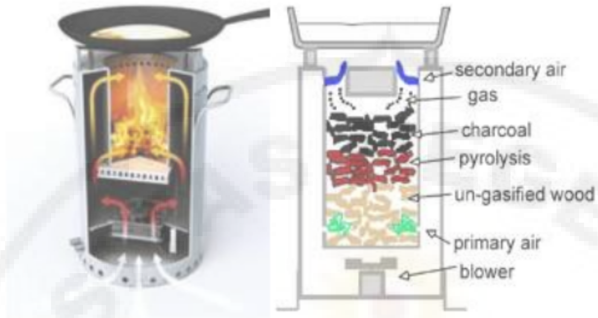


**Figure** 1. Biomass Gas stove [19]

The study conducted by Dinesh et al. (2017), biomass is used as a natural fuel for testing family size biomass gasification stoves (figure 1) , fabricating and to get their efficiency compared to traditional stoves. Mild steel sheets and mild steel rods are used as materials for making stoves, while rice husks, sawdust and coal are taken to be tested and sought for efficiency. An aluminum pot with a capacity of 22 liters and boiling 20 liters of water was used to test the performance. It was found that the thermal efficiency of the rice husk and sawdust biomass gasification stove was 26.81 and 28.64 percent, respectively. Biomass gasification stoves have high cooking speeds and can reach higher temperatures than traditional stoves, due to their concentric flame and low smoke combustion [18]. Adedayo, Owoola, and Ogunjo (2018) have compared the performance of kerosene stoves, LPG and biomass gasification stoves, palm shell fuel is used as fuel for biomass stoves, evaluated using the combustion zone test and fuel conversion rate. After construction, the performance of the stove was compared with the kerosene and LPG gas stove with a water boiling test. The results obtained show that the biomass stove is faster than the kerosene stove and better than the gas stove [19].

Klius et al. (2018) has compared the thermochemical process of converting biomass into energy, especially in the manufacture of biomass gasification stoves for cooking. Given the high energy efficiency and environmental friendliness, the biomass gasification stove significantly exceeds the traditional stove. The theoretical analysis of the gasification and combustion processes of the fuel flowing in the stove is considered. Several samples of stoves with reactor volumes of 5.5 to 9.7 liters were made and trials were carried out for various types of biofuels (pellets from soft wood, pine sawn wood, wood chips from hardwood, straw briquettes, sunflower husks, Buckwheat husks.From the test results it was found that the efficiency of the stove is about 30% which is approximately 3 times higher than that of a traditional direct combustion stove, and the average heat power of the biomass gasification stove is 0.71–1.78 kW, comparable with thermal power from household stoves running on LPG. Fuel consumption and the specific combustion rate of the fuel are determined by the air supply The use of thermal insulation of the hull allows not only to reduce significant heat loss to the environment but also to avoid burns if the person touches the stove accidentally. The advantages of this stove are: ecological compatibility; economy; mobility. Potential consumers ko importers are residents of non-gasified areas, summer residents, tourists [20].

The increased interest has led to significant research efforts towards finding novel technologies in clean energy production [1]. Consequently, the merits of a thermo-electric generator (TEG) have promised a revival of alternative means of producing green energy. It is, however, impractical to account for the cost of thermal energy input to the TEG which is in the form of final waste heat [21].

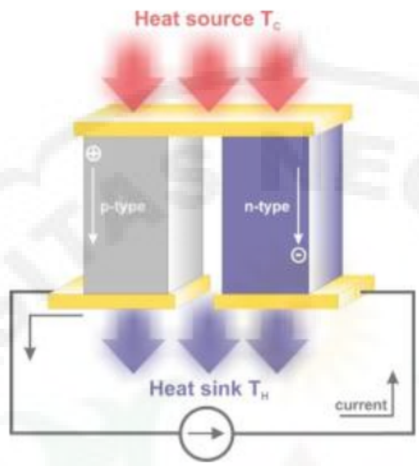


**Figure 2**. Work Principle Themoelectric Generator

Thermoelectric power generators as shown on figure 2, convert the thermal energy into the electrical energy directly [21]. Moreover, the TE technology is environmentally friendly. It has no moving parts and is longlived. Although their efficiency is about 5–10%, considering reuse of waste energy gain, their efficiency cannot be ignored [22]. Thermoelectric generator is a solid state energy harvester which can convert thermal energy into electrical energy in a reliable and renewable way [23]. Over the past decades, the human body has been considered a good source of heat for harvesting electrical energy through wearable thermoelectric generators. It may be an alternative power generation technique compared to other conventional ones used for many wearables [24]. The thermoelectric generator generates sufficient energy for each wireless sensor mode [25].

Thermoelectrics generally use materials that are semiconductors or in other words use solid-state technology [26]. The structure of the thermoelectric can be seen in figure 2. The figure shows a thermoelectric structure consisting of an arrangement of P-type elements, namely a material that lacks electrons, and also consists of an arrangement of N-type elements, namely a material with an excess of electrons. Heat enters on one side and is removed from the other. The heat transfer produces a voltage across the thermoelectric junction and the magnitude of the resulting electric voltage is proportional to the temperature gradient [27]. The review by Pourkiaei et al. (2019) explains the increasing interest in thermoelectric technology and applications. Currently, thermoelectric technologies such as thermoelectric generators (TEG) and thermoelectric cooling systems (TEC) can be used as heat loss recovery thermodynamic units for power production in remote areas [28]. Since biomass stoves are widely used in underdeveloped countries where there is no access to electricity, it is appropriate to use TEGs by sticking them to the side of the stove. This will increase the actual usability and efficiency of the stove [29]. A thermoelectric generator (TEG) can be used to recover waste heat and convert it to electricity based on the principle of the Seebeck effect [30]. Patowary and Baruah (2019) have conducted a study trying to test the feasibility of integrating a TEG module with a clay cooktop that has been approved by the Ministry of New and Renewable Energy (MNRE) named Sukhad in India using basic heat transfer and thermoelectric equations. Preliminary tests show the TEG integrated cooktop has the potential to generate 2.7 W of electrical power and illuminate a 3 W LED bulb [31].

## 2. Material and Method.

Research equipment for measuring the temperature of both sides of the Peltier and the voltage generated by the TEG is shown in figure 3. Ten units of Peltier TEG mounted in series on the stove wall, connected to an AVO meter to measure the voltage generated during the combustion of each biomass.

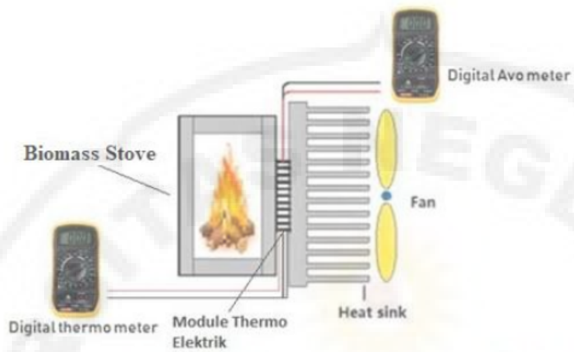


**Figure 3**. Experimental scheme

The hot side ($T_1$) is attached to the stove wall, while the cold side ($T_2$) is installed with a heat sink. On the cold side and hot side, a thermocouple is installed to measure the temperature of both sides of the Peltier so that the temperature difference ($\Delta T$) of the two Thermoelectric Generators (TEG) is obtained, the difference in temperature generated by the use of different biomass as fuel is recorded as data. This experiment was carried out for various types of biomass, namely: Wood chips from Making Frames, Coconut Shells, Candlenut Shells and Corn Cobs. For each of these biomass fuels, the electrical voltage generated is measured.

## 3. Results and Discussion

### *3.1. $\Delta T$ both sides of the peltier on each biomass fuel*

Each biomass has different combustion characteristics, some types of biomass are difficult to burn at first, but after that they produce high temperatures. Other biomass smolders quickly, but produces temperatures that are not too high.

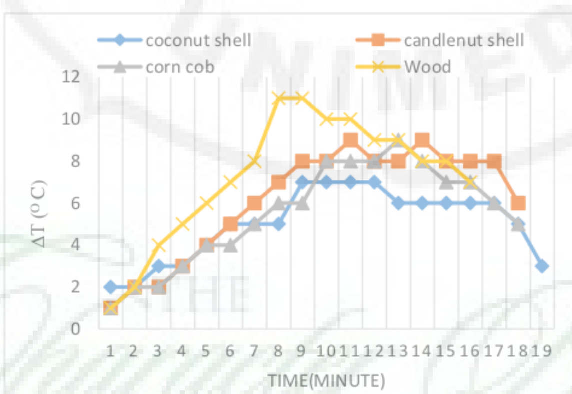


**Figure 4**. $\Delta$ T both sides of the peltier on each biomass fuel

Figure 4 shows that the wood chips produce a higher temperature difference than other biomass, but at the end it is lower than the candlenut shell temperature.

### 3.2. Electric Voltage generated by each biomass

Figures 4 and 5 show that the voltage generated by TEG is proportional to the difference in temperature, these two graphs have the same trend for each biomass. Figure 5 shows that in the early minutes the voltage generated by the corncob is lower than the candlenut shell voltage, but the peak of the corncob is higher and then ends lower.

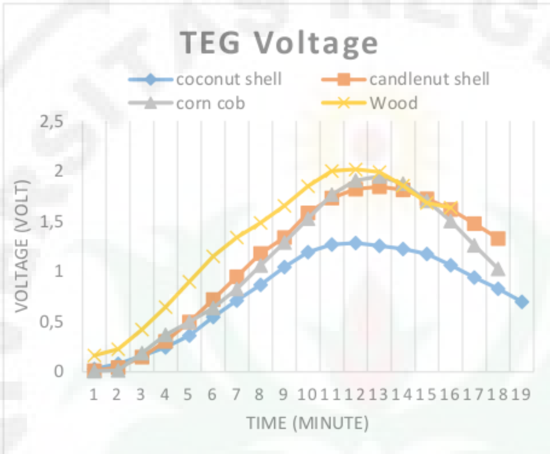


**Figure 5**. The electric voltage generated by each biomass

### 3.3. Average voltage generated per biomass

Figure 6 shows the highest average voltage produced by wood chips, followed by candlenut shells, corn cobs and coconut shells. This is unique, although the calorific value of coconut shells (19,5 MJ/kg) is higher than hard wood (18,8 MJ/kg) and corn cobs (5.32 MJ/Nm$^3$) [32], [33] but the highest average voltage is produced by wood. This shows that the voltage generated by TEG in the furnace is influenced by the characteristics of biomass combustion.

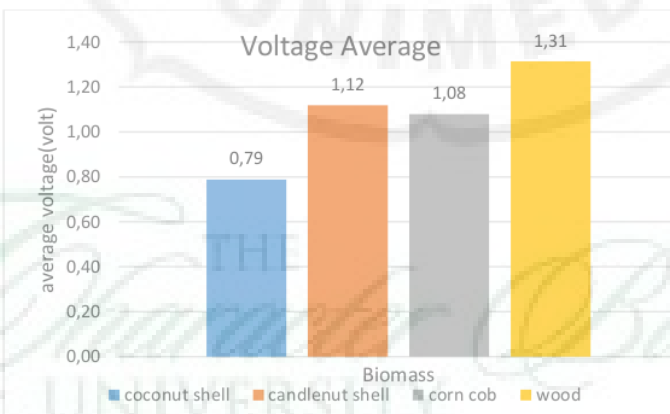


**Figure 6.** Average voltage generated per biomass

## 4. Conclusion

Thermoelectric which is installed in a biomass stove can generate electricity. Each biomass have different combustion characteristics. The voltage generated is proportional to ΔT on both sides of the peltier. The electricity generated is not always proportional to the heating value of the biomass.

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