Heat radiation approach for harnessing heat of the cook stove to generate electricity for lighting system and charging of mobile phone

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Abstract. This study is based on the potential of thermoelectric coupling such as the thermoelectric cooler module. A thermoelectric cooler converts the heat coming from the cook stove into electricity and store in a battery. A dc-dc boost converter will be used to produce enough voltage to light a minimum house dwelling or charge phone battery. This device will be helpful to those that faces a problem on electricity especially in the isolated areas. The study aims (1) to harness heat from the cook stove up to 110 °C; (2) To automatically cool-off the system to protect the thermoelectric cooler from damage due to excessive heat using an electronic solenoid; (3) To store energy harnessed in the battery; (4) To amplify the output voltages of the battery using DC to DC boost converter for lighting system and charging of mobile phone battery. From various tests conducted, it can fully charge a mobile phone in 3 hours observing the unit’s battery voltage drop from 4.06V to 3.98V. In the testing it used different orientation of steel rod by conduction to transfer heat and by radiation through tubular steel with its different dimensions. Most recent testing proved that the 2x2x9 tubular steel by radiation had the best result. The temperature reached more than a hundred degree Celsius that met the objective. The test resulted of boosting the voltage of the battery output from 3.7V to 4.96V on the average. The boosted voltage decrease as the system’s cool-off mechanism operated when the temperature reached above 110 degree Celsius decreasing output voltage to 0.8V resulting the boosted voltage to drop to zero. Therefore, the proponents concluded that heat waste can be converted to electrical energy by harnessing heat through radiation, with the help of TEC that generates voltage for lighting and can be boosted to be used for mobile charging. Furthermore, the study proved that the excess heat can damaged the TEC which was prevented by using of cooling-off mechanism, making it more useful for longer time.

1. Introduction
The foundation of this research is the study of Alan Pnakovich in the year 2009 of American Heritage School, Plantation, Florida about the Seebeck and Peltier Thermoelectric effects, the two junctions that are made between two different conductive metals with different temperatures will create a voltage from the temperature difference of the two junctions [1]. Thermoelectric coupling process is literally associated with thermal and electrical phenomena. It can directly convert thermal energy into electrical energy or vice versa. [2]. The TEC has a parallel thermal connection, hot side and the cold side. It will serve as the input in the thermoelectric cooler. A low voltage of the order of tens of micro voltage per kelvin is generated. This phenomenon is called Seebeck effect [3]. The power generation of thermoelectric devices are low efficiency at heat-to-electricity, which typically near to 5% thus the thermoelectric device is limited to output only a low voltage.
This research is motivated by the study of O'Shaughnessy in his study about the “Small scale electricity generation from a portable biomass cook stove that thermoelectric module is capable of delivering small amounts of off-grid electricity”. A single thermoelectric module is utilized to convert a small portion of heat from the stove to electricity [4]. The research started the initial study in 2011 with a project feasibility study in “Direct Conversion of Heat to Electrical Energy” [5]. The researcher’s objective was to supply electricity to the isolated areas using the heat from the cook stove that is harnessed using the metal rod using the thermoelectric generator (TEG). In the study of Daniel Champier and his team of Thermoelectric Generator Incorporated in a Multifunction Wood Stove, a fixed water tank in the stove as the exchanger is being attached in the cold side of the TEC for the coolant [6]. This type of coolant helps the TEC to produce greater power compared to other type of coolants. Liquid in cold side can sustain a very large differential temperature even with an elevated ambient temperature. This was adapted by this study. The research also implemented boost converters used to convert the lower input voltage into higher output voltage [7]. The voltage regulator process the regulating of the voltage of the TEC before storing it in a battery. Voltage amplification step-up the battery voltage to supply the electronic module, temperature sensor and to charge a mobile phone battery. The electronic module of the system, consist of a battery storage where the output voltage from the coupling unit is simply stored. In this study, the proponent used secondary batteries (rechargeable) with a specification of 5000mAh, 3.7 V single battery.

2. **Significance of the study**

There are many kinds of waste heat, and most of it just disappears in the air and is not useful in any kind of way. Waste heat from a cook stove is abundant, and every household uses it. Turning waste heat into electricity can be a great help to each community in areas experiencing power shortage with special notation of climate change.

According to the law of conservation of energy, energy can neither created nor destroy. It can only convert from one form to another [8]. Thermoelectric module converts heat waste to electrical energy and store in an appropriate battery bank by implementing a DC charger circuit in order to be a useable source of electricity. A single thermoelectric module is utilized to convert a small portion of heat from the stove to electricity. A thermoelectric module has an ability to generate power and provide a source of heating and cooling. Each of which is consist of p-type and n-type semiconductor that is connected thermally in parallel and electrically in series. The development of a simple and efficient means of converting waste heat to electricity would be a good alternative source of energy that can help the community’s problem of power shortage.

3. **Methodology**

The researchers studied the concepts and design of the heat to electricity electronic module needed to convert the bursting heat energy to electrical energy. The cooling-off mechanism was designed and installed to a heat source to protect TEC from excessive temperature required. Metallic rod is attached in a way it is configured to conduct heat. The temperature sensor on the metal plate (hot side of the thermoelectric cooler) will sense if the heat flowing is exceeding in the set temperature. It will trigger the solenoid lock to actuate. The thermoelectric cooler (TEC) is stand-off between the metal plate and galvanized iron container to have temperature difference across the hot side and the cold side to convert the heat to electricity. The output voltage from the thermoelectric coupling unit will be the inputted to the circuit of a DC to DC boost converter to amplify the generated power of the thermoelectric coupling unit to attain the output needed to charge the battery. The generated electricity from the thermoelectric cooler unit will be stored in the battery storage with a specification of 2300 mAh, 3.7 volts rechargeable battery. It will undergo voltage amplification process to charge a mobile phone battery of 5 Volts.

4. **Test results**

4.1. **Harnessing heat from cook stove and storing energy harnessed in the battery**
Harnessing heat from the cook stove in terms of heat temperature were monitored every 1 hour of cooking time. The following figures show the testing of the proponents between conduction and radiation.

In heat harnessing, evaluation was conducted in stove connected with metals that transfers heat through conduction. Figure 2 show the thermal conduction of stove within 60 minutes of testing. As indicated, the first set up used solid metal that does not reach 100°C which does not meet the objective. There is an instance of a sudden dropped which was caused by the lack of charcoal to produce heat. For the figure 3 used radiation method, it indicated the five (5) sizes of tubular used for radiation. For the 2x2x11 tubular, the heat harnessing was good, for it continuously increases until it reach 100°C then cool-off which caused the temperature to decreased down to below 90°, then, when the cooling-off mechanism changed actuation, the temperature increase again. Compared to other sizes of the tubular used; only the 2x2x11 has reached 100°. The two figures indicated that using radiation to harness heat is better than harnessing heat via conduction. Figure 4 compared the heat transfer via radiation and conduction. Copper was used as a thermal bridge in conduction graph. Knowing copper that has high thermal conductivity and TEG is used capable of handling 800°C. On the other hand, by radiation, tubular was used as thermal bridge and TEC as its module. Tubular is much cheaper than copper and TEG is not available locally in the Philippines. TEC can only handle 110°C and may be damaged if the temperature exceeds that limit. Tubular is enough for the TEC to function.

In figure 5, it was shown that the charging of battery unit continuously increases until it fully charged to 4.2V. It took almost 3 hours to fully charge the battery of the unit.
Figure 3. Heat harnessing via radiation

Figure 4. Comparing of radiation and conduction

Figure 5. Charging of the battery of the unit
4.2. Monitoring the “cooling-off” mechanism
To monitor the “cooling-off” mechanism, the objective is to cool-off the system not exceeding 110°C. From the several testing conducted, the histogram in Figure 6a and Figure 6b shows that the sensor can sense the maximum temp of 110°C and actuated the solenoid to cool-off the system.

![Figure 6a. Monitoring of cooling-off mechanism for different condition (close to open)](image_url)

![Figure 6b. Monitoring of cooling-off mechanism for different condition (close to open)](image_url)

4.3. Amplifying the voltage of the battery and effectiveness fo the device
In figure 7, with the input voltage of 3.7V to the battery the highest boosted voltage is 4.96V. The required charging voltage for the phone of 5V is also indicated in the figure. Shown also in Figure 8 are the boosted voltage required to charge the unit. It decreased because it cools-off when the temperature decreases resulted the output voltage of the TEC to drop below 0.8V, the boosted voltage will then result to 0V. The required voltage to charge the mobile unit is 3.7V. Figure 9 shows the linear relationship of time and battery charge percentage of the mobile phone. This figure indicates that the system unit can charge a battery of mobile phone with a specification of 5V and 2300 mAH. In several testing, charging time of the mobile phone battery required 3 hours to fully charge.

In figure 10, comparing the light intensity with the other study, the light intensity using a sun king lantern lasted for five hours with a 2 watts light (25lux). Comparing the previous study with the proposed method, the 1 watt LED lasted for three hours of fixed intensity of 25 lux and continuously decrease as it dropped to 15 lux at the end of 5 hours.
Figure 7. Boosted battery voltage of the unit

Figure 8. Boosted voltage for charging the unit

Figure 9. Percent charging mobile phone battery
5. Conclusion
Based on the various data and results of the study, the proponents concluded that the use of radiation as a way for heat harnessing performed better than that of conduction. By using TEC instead of TEG can produced equal performance with comparable application taking into account the use of “cooling-off” mechanism to prevent the TEC from excessive heat which may cause damage or affects the performance. Safekeeping the TEC from damage made it more useful for longer time.

6. Acknowledgment
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