Generating Electricity From A Temperature Gradient In Compost

Rajan Leung

The goal of the project was to provide another source of generating renewable energy, while combating food waste and promoting composting. This project served as a prototype and a proof of concept since. There is limited knowledge in the field regarding the generation of electricity from compost via thermoelectric generators. This project was conducted on a smaller scale with only 15 thermoelectric modules and using a 2 gallon container. The compost bin generates electricity from a temperature difference between the inside of the compost bin and the outside temperature. Overall, the bin generated 5 volts with a 57°C temperature gradient. The voltage produced is significant enough to be used to power and charge small electrical devices.

Introduction

Approximately 319,681,923,344 Joules of electricity are used each year (Larsen et al. 2019). Approximately one fifth of the world's energy supply is renewable (Puiu 2018). The non-renewable energy consumption contributes to climate change and harms our planet. My project's goal is to provide another source of generating renewable energy, while combating food waste and promoting composting. Compost promotes the "recycling" of nutrients and nitrogen back into the environment. It is a clean and natural process that is great for the plants. It's a "greener" alternative to chemical fertilizers. The compost bin, on a larger scale, would be able to generate electricity and incentivize individuals to compost. The aim of this project is to construct a compost bin capable of generating electricity from thermal energy. This project is meant to serve as a prototype and a proof of concept. Since there is limited knowledge in the field regarding the generation of electricity from compost via thermoelectric generators. Most of the research conducted has been on generating electricity from compost through means of extracting biogas such as methane. This project is going to be conducted on a smaller scale with only 15 thermoelectric modules and using a 2 gallon container due to financial and time constraints.

Thermoelectric generators convert the difference in temperature into electricity. The generators work off of a principle called the Seebeck effect (TEGmart 2018). Thomas John Seebeck discovered that a temperature difference between two metals creates a voltage difference. This is related to heat transfer in which heat transfers from one object to the next, to create a stable temperature. When one side of the thermoelectric generator is hot and the other is cold, the two temperatures collide and generate an electrical current through heat transfer. This process is similar to the peltier effect. The peltier effect is the opposite, in which an electrical current is used to heat one object and cool the other. This technology is found in regular thermoelectric coolers, such as in computer parts, refrigerators, and water coolers. Thermoelectric generators have been found to cost less than solar panels. Thermoelectric generators, also, do not depend on the sun, but rather any difference in temperature. These modules are so effective that agencies such as NASA have employed them on the Voyager and Cassini space probes (Allain 2017).

According to Cornell University, the heat of the compost is dependent on the volume of compost, moisture content, and aeration (Trautmann 1996). Compost, with more than 38 litres in volume, can heat up to 40-50°C within 2 to 3 days. Compost, with approximately 2-3 litres in volume, will heat to a maximum of 30-4°C. Commercial sized composts may heat up to 60-70°C within 3-5 days. Moisture content of 50-60% is considered optimal for achieving these temperatures. The oxygen concentration should be around 15-20% for optimal temperatures. Compost should consist of 25 parts carbon to 1 part nitrogen. This means that items such as fruit scraps, dry leaves, and yard clippings should be prioritized if maximum heat is to be achieved.

Similar work has been conducted in the field of biomass energy. In various "waste to energy" processes, the compost is broken down and fermented (DoItYourself.com 2010). Eventually, methane gas is created as a byproduct of the reaction. The end result yields biofuel and healthy fertilizer. The biofuel can undergo combustion to create electricity or be used as a natural gas. The fertilizer can be used to grow more plants. The only requirement is that the compost is methane rich and that the temperature is optimal for the fermentation process. A company called HomeBiogas has created a device capable of harnessing biofuel from compost (HomeBiogas 2019). The device works when the bacteria digests the compost and releases biofuel. The machine requires a minimum of 6 litres of compost to function properly. The machine produces approximately 2 hours' worth of "cooking gas" a day. Many other research projects, although not to the scale of HomeBiogas, have created and tested compost bins that generate electricity from methane. However, the electricity generated from the compost is usually through burning compost or the compost-derived methane, both of which are harmful to the environment and contribute to greenhouse gas emissions. However, limited research has been conducted on generating electricity from the heat of compost as opposed to biofuel. Compost naturally heats up, and the thermal energy can be cleanly transferred into electrical energy.

Materials and Methods

In order to construct the electricity-generating compost bin, a Nova Products kitchen food waste bin (8 litres) was purchased. Holes were cut out of this bin, using an exacto knife, to make space for the 15 thermoelectric modules. Out of the 15 thermoelectric modules, 10 were Yikeshu thermoelectric modules (40mm by 40mm), 1 was a 1 RobotShop.com peltier thermoelectric cooler module, and 4 were CUI Inc. thermoelectric modules (10mm by 10mm). This is shown in Figure 1. Each module was wrapped in aluminum foil and hot glued in place, using a hot glue gun. Figure 2 shows how each of the modules were attached together in series using a spool of red insulating wire, wire strippers, and a soldering pen. A Pololu 5V step-up voltage regulator and the usb port were then attached to the breadboard using a soldering pen. Figure 3 shows how the two ends of the modules were attached to a Banggood solderless breadboard (8.5cm by 5.5cm) and how the breadboard was attached to the compost bin.

Testing of the device began after the compost bin was assembled. A heat gun and glass marbles simulated compost and its heat absorption. Testing occurred in cold temperatures. This allowed for a greater temperature gradient between the inside and the outside of the compost bin. A Sparkfun electronics VC830L digital multimeter was used to measure the voltage and current of the electricity generated. The multimeter was connected to the two ends of the breadboard and was tested in two spots, before the voltage regulator and after the voltage regulator. A Taylor scientific thermometer was used to measure the temperature inside and outside of the device in order to calculate the temperature gradient.

Trial:	Maximum Voltage Reached:	Temperature inside the compost bin:	Temperature outside:	Temperature Gradient:
Trial 1:	0.2V	15°C	-2°C	17°C
Trial 2:	0.3V	25°C	-3°C	28°C
Trial 3:	0.4V	30°C	2°C	28°C
Trial 4:	5V (0.8V before)	35°C	4°C	31°C
Trial 5:	5V (1.1V before)	80°C	23°C	57°C

Table 1: This table shows the maximum voltage achieved in each trial. In trials 4 and 5, the voltage "before" is the voltage recorded before the voltage regulator. The final output voltage recorded in trials 4 and 5 was 5V due to the voltage regulator. The temperature gradient or the difference in temperature between the inside tile and the outside tile was also recorded.

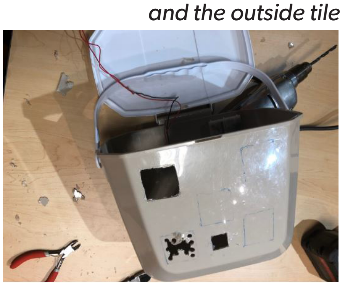

Figure 1: The compost bin during construction. The tiles were inserted in between the compost bin walls, so that each side was exposed.

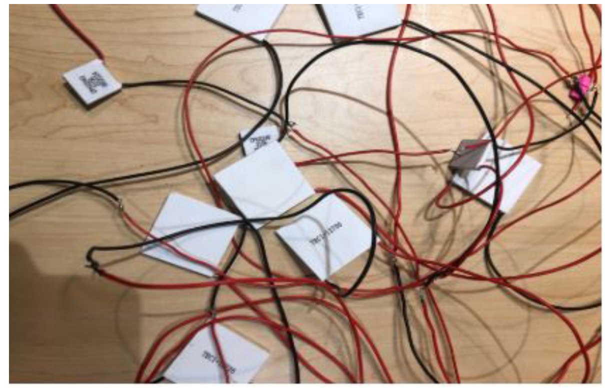

Figure 2: The thermoelectric generators, after being soldered together in series.

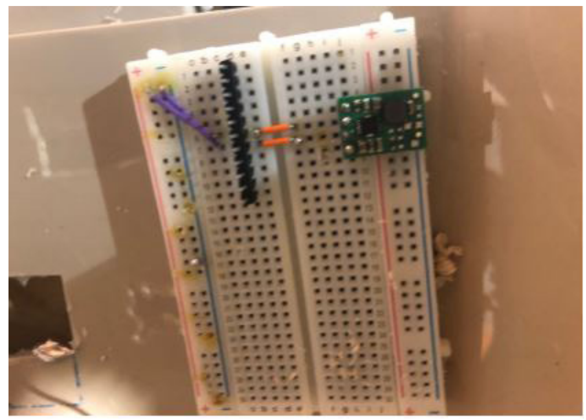

Figure 3: The wiring of the breadboard. The image shows the purple and orange wires connecting the negative and positive terminals to the green chip. The green coloured chip is a voltage regulator that takes the input voltage and gives an output voltage of 5V. The pins are used for testing the voltage before the voltage regulator. Note that the tile leads are missing in this photo as well as the USB slot.

Results

The aim of this project is to construct a compost bin capable of generating electricity from thermal energy. Five trials were conducted. Each trial involved heating glass marbles using a heat gun, in order to simulate compost. The current size of the compost bin was too small to generate electricity from actual compost. The first trial involved 4 thermoelectric generators and 1 thermoelectric cooler. The system was able to produce a voltage of 0.2 Volts. The outside temperature was around -3°C and the inside temperature was about 15°C. Without making any modifications, the second trial was able to produce 0.3V. The outside temperature was about -3°C and the temperature inside the compost bin was about 25°C. The third trial involved the same compost bin. This time, instead of testing individual tiles, the experiment tested all 5 of the tiles. A slight modification was made by rewiring and soldering the compost bin. The maximum voltage achieved was 0.4V. The inside temperature was 30 and the outside temperature was 2 . However, the compost bin started to smoke after 7 minutes of the heat gun and the experiment was stopped.

The fourth trial involved a modification of the compost bin containing 15 tiles. Ten of these thermoelectric generators were brand new, and when tested in parallel, two of the tiles could generate 0.55v with a 33°C temperature gradient. The compost bin was rewired so that the tiles were in parallel as opposed to series. The outside temperature was 4°C and the inside temperature was approximately 80°C. However, much of that heat neither reached the edges of the compost bin nor the bottom since the interior temperature was only 35°C. The voltage reached was 5V. However, the compost bin began to overheat after 10 minutes. The heat gun started to get very hot and resulted in the marbles smoking. The temperature after the voltage regulator was only 0.15V when the compost bin was smoking. This may be because the voltage regulator overheated. The voltage before the regulator was 0.8V during the experiment, before the smoke.

In the fifth trial, a hole was cut into the lid of the compost bin for the heat gun to be placed. The inside temperature was at 80°C. The outside temperature was 23°C. The maximum voltage achieved was 1.1V. With the voltage regulator, the maximum voltage was 5V. However, the compost bin started to release smoke and the heat gun was stopped after 8 minutes. The temperature afterwards was 50°C and reached a maximum voltage of 0.2V.

Overall, the compost bin was able to conduct electricity. This data can be seen in the above Table 1. In trials 4 and 5, the voltage reached a maximum of voltage of 5V. This was with the voltage regulator. Without the voltage regulator, the maximum voltage reached was 1.1V, using 10 thermoelectric generators. This was reached with a 57°C temperature gradient.

Discussion

The compost bin was able to conduct electricity successfully. Each test revealed that the compost bin was able to conduct electricity. However, the compost bin was not able to reach a maximum of voltage of 5 volts, despite numerous attempts. The voltage generated was not enough to be of any significant use. However, on a larger scale, this project would be very effective.

The project, although it achieved the scope as a proof of concept, had a few limitations. If there were more thermoelectric generators, then the voltage would have been increased greatly. The volume of the compost bin was only 8 litres and not large enough to generate a sufficient amount of electricity. Most home garden size compost bins are around 100-150 litres and are large enough to generate sufficient amounts of electricity to power multiple loads. Real compost was unable to be used due to the low heat produced from the small compost bin size and the limited compost materials. On a larger scale, compost would be effective as it would generate heat at a consistent rate, in comparison to using a heat gun which does not consistently produce heat when the heat gun is turned off.

In conclusion, the results support my hypothesis that my compost bin would be able to generate electricity from heat. Overall, I was able to reach 1.1V of electricity using a heat gun and my compost bin. This was with a 60°C temperature gradient. The compost bin was effective at retaining heat and the thermoelectric generators functioned well. My background research corroborates my findings and supports the idea that compost would be able to consistently give off heat over time. Further testing on a larger scale with real compost needs to be done. The current prototype compost bin acts as a valid proof of concept because it is able to generate electricity. However, this prototype is not feasible on a larger scale. The technology used is very expensive and does not produce enough electricity yet.

Further work can be conducted through constructing more compost bins that generate electricity. These compost bins would be larger in size and would be approximately 38 litres in size and would use approximately 71 thermoelectric generators in order to keep the ratio of generators to volume the same. More quantitative data, on the voltage and current generated, needs to be collected in order to ensure that this will be a viable method for generating electricity. Research should be conducted on larger scales such as on compost piles found on farms as well as using real compost. This would give more accurate results and may support a need for this device to be used.

References

Allain, R. (2017, December 20). Build a Thermoelectric Generator, Like the Ones That Power Deep Space Missions. Retrieved March 7, 2019, from https://www.wired.com/story/build-a-thermoelectric-generator-like-the-ones-that-power-deep-space-missions/

DoItYourself.com. (2010, March 22). How Organic Waste is Converted Into Electricity. Retrieved March 7, 2019, from https://www.doityourself.com/stry/how-to-convert-organic-waste-into-electricity

HomeBiogas. (2019). Introducing the revolutionary HomeBiogas System. Retrieved March 7, 2019, from https://homebiogas.com/

Larsen, E., Olsen, K. B., & Emanouilov, V. (2019, March 7). Live statistics about energy & climate. Retrieved March 7, 2019, from http://www.theworldcounts.com/themes/energy_and_climate

Puiu, T. (2018, June 26). How much renewable energy does the world use. Retrieved March 7, 2019, from https://www.zmescience.com/ecology/climate/how-much-renewable-energy/

TEGmart. (2018, April 21). Scientific Guide to Understanding and Using TEG Power! Retrieved March 7, 2019, from https://www.tegmart.com/info/guide-to-http://www.citationmachine.net/items/new#understanding-and-using-teg-power-and-products/

Trautmann, N. (1996). Cornell Composting - Compost Physics. Retrieved March 7, 2019, from http://compost.css.cornell.edu/physics.html