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Electricity Generation from Plastic Waste Using Thermoelectric Generators

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Abstract

Plastic waste is a problem for the environment because it doesn't break down and people are using more and more of it. This paper talks about a system that turns plastic waste into electricity using special devices called thermoelectric generators or TEGs for short. The system has parts: a chamber where the plastic is burned in a controlled way, an SP1848-27145 TEG module, a heat sink, a device that boosts the voltage, an inverter that changes the voltage from current to alternating current and a unit that filters the air. When plastic is burned it produces heat, which is then turned into electricity by the TEG through something called the Seebeck effect. The results of the experiment show that the voltage output went up from 0.8 volts to 5.3 volts when the temperature difference across the TEG went up from 30 degrees Celsius to 140 degrees Celsius. The most power that was produced was 625.4 milliwatts.The air filtration system that is part of the setup helps reduce the stuff released during burning. The system we propose is a cost- way to deal with plastic waste and make a small amount of electricity at the same time.

Keywords; Plastic Waste, Waste- to-Energy, Thermoelectric Generator, Seebeck Effect, Renewable Energy, Electricity Generation.

INTRODUCTION

Plastic waste is a problem for our environment. This is because plastic does not break down easily and it is getting piled up in landfills and water bodies. The usual ways of getting rid of waste like putting it in landfills or burning it are making our air dirty and releasing bad gases. At the time we need to find new ways to make energy because people are using more and more energy. This paper is about a system that uses a machine called a thermoelectric generator to turn the heat from burning plastic waste into electricity. The system makes the electricity stronger with a converter and it can be changed into the kind of power we use at home. The system also has a filter to clean the air. This system is a way to deal with plastic waste and it also makes useful electricity. Plastic waste is turned into something, with this system, which is a big help. The system generates electricity from waste, which is a good thing.

LITERATURE REVIEW

Several researchers have investigated electricity generation from waste materials. Waste-to-energy technologies have gained significant attention as sustainable solutions for both waste management and energy generation.

- Twidell and Weir [1] discussed various renewable energy resources and highlighted the importance of recovering energy from waste materials to meet growing energy demands.
- Rowe [2] explained the principles and applications of thermoelectric generators (TEGs), emphasizing their ability to directly convert heat into electrical energy through the Seebeck effect.
- Arena [3] reviewed municipal solid waste gasification technologies and demonstrated their potential for energy recovery while reducing landfill dependency.

- Demirbas [4] examined waste management and waste conversion processes, highlighting the environmental and economic benefits of converting waste into useful energy.
- Singh and Laurenti [5] evaluated the environmental performance of various waste-to-energy technologies and reported their role in reducing environmental pollution and improving resource utilization.
- The U.S. Environmental Protection Agency (EPA) [6] identified waste-to-energy systems as a viable approach for sustainable waste management and renewable energy generation.

Although previous studies have demonstrated the feasibility of waste-to-energy conversion and thermoelectric power generation, limited work has focused on low-cost thermoelectric generator based systems for recovering electrical energy from plastic waste combustion with integrated emission control. Therefore, this study proposes a simple and cost-effective TEG-based prototype for converting plastic waste into useful electrical energy while minimizing environmental impact.

OBJECTIVES

The major objectives of this research are:

- To convert plastic waste into useful electrical energy.
- To develop a thermoelectric generator-based waste-to-energy prototype.
- To reduce environmental pollution through controlled combustion and filtration.
- To provide a low-cost alternative energy source.
- To evaluate system performance under varying temperature conditions.

SYSTEM DESIGN AND IMPLEMENTATION

A. System Components

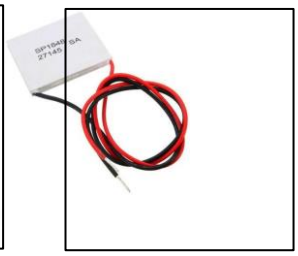
The proposed system consists of:

- Fire Box
- SP1848-27145 Thermoelectric Generator Module

Aluminum Heat Sink

- DC–DC Voltage Booster
- DC–AC Inverter
- LED Load
- Air Filtration Unit

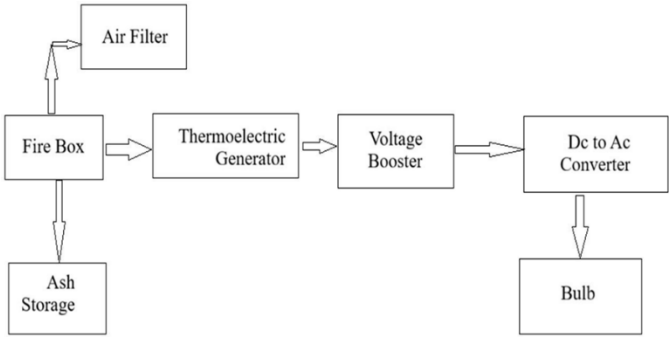
Fire Box



TEG Module (SP1848-27145)

The air filter is taken from a Yamaha Gladiator

B. Block Diagram



C. Working Principle

Electricity Generation from Plastic Waste Using Thermoelectric Generators (TEGs) works on the principle of the Seebeck Effect, which states that a voltage is generated when there is a temperature difference between two sides of a thermoelectric material.

- Plastic Waste Combustion: Plastic waste is placed inside a controlled combustion chamber (fire box). When the plastic burns, it produces heat energy.
- Heat Transfer to TEG: The hot side of the SP1848-27145 Thermoelectric Generator (TEG) module is attached to the combustion chamber. The cold side

is connected to an aluminum heat sink to maintain a lower temperature.

- Electricity Generation (Seebeck Effect): Due to the temperature difference between the hot and cold sides, the TEG generates a DC voltage. A larger temperature difference produces higher voltage and current.
- Voltage Boosting: The generated DC voltage is relatively low. A DC-DC boost converter increases the voltage to a usable level.
- DC to AC Conversion: The boosted DC voltage is supplied to an inverter. The inverter converts DC power into AC power for operating electrical loads.
- Load Operation: The generated electricity can be used to power small loads such as LEDs and other low-power devices.
- Emission Control: Smoke produced during combustion passes through an air filtration unit. The filter helps reduce particulate matter and harmful emissions.

Working Flow Diagram

Plastic Waste → Combustion Chamber → Heat Generation → TEG Module → DC Voltage → Boost Converter → Inverter → AC Output/Load

Principle Equation: The voltage generated by the TEG is: $V=S\times\Delta T$ Where:

V = Generated Voltage (V), S = Seebeck Coefficient (V/°C), ΔT = Temperature Difference between hot and cold sides (°C).

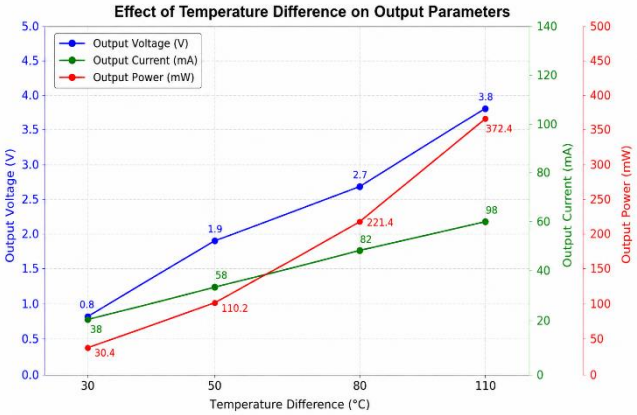
D. Experimental Setup:

The experimental setup includes mounting the TEG module on the combustion chamber, attaching a heat sink using thermal paste, connecting the voltage booster and inverter, and

Powering an LED load. Measurements of temperature, voltage, and current were recorded using a digital thermometer and multimeter.

V. RESULTS and DISCURSSIONS

a. Experiment Result



Temperature Difference (°C)	Output Voltage (V)	Output Current (mA)	Output Power (mW)
30	0.8	38	30.4
50	1.9	58	110.2
80	2.7	82	221.4
110	3.8	98	372.4

B. Discussion

- The experimental results demonstrate the successful conversion of plastic waste into electrical energy using a thermoelectric generator (TEG), thereby achieving the primary objective of the study. The system operates on the Seebeck effect, where a temperature difference between the hot and cold sides of the TEG generates electrical voltage.
- As the temperature difference across the TEG increased from 30°C to 110°C, the output voltage increased from 0.8 V to 3.8 V, while the output current increased from 38 mA to 98 mA. Consequently, the output power rose from 30.4 mW to 372.4 mW. This trend confirms that the electrical output of the system is directly dependent on the temperature gradient produced by the combustion of plastic waste.
- The results validate the effectiveness of the developed TEG-based waste-to-energy prototype and demonstrate its capability to recover useful energy from plastic waste. The incorporation of a DC–DC voltage booster further enhanced the usability of the generated power by increasing the low TEG output voltage to a practical level. In addition, the air filtration unit helped reduce particulate emissions generated during combustion, supporting the objective of minimizing environmental pollution.
- Overall, the experimental findings confirm that the proposed system provides a low-cost and environmentally conscious approach for simultaneous plastic waste management and small-

scale electricity generation. The study also establishes that higher temperature differences lead to improved system performance, fulfilling the objective of evaluating the prototype under varying operating conditions.

VI. BENEFITS

- **Effective Plastic Waste Management:** The system helps reduce the accumulation of plastic waste by converting it into useful energy, thereby minimizing environmental pollution.
- **Electricity Generation from Waste:** It converts thermal energy produced during plastic waste combustion into electrical energy using thermoelectric generators.
- **Renewable and Alternative Energy Source:** The generated electricity can be utilized for small-scale applications, reducing dependence on conventional energy sources.
- **Low-Cost Implementation:** The prototype uses readily available and inexpensive components such as TEG modules, heat sinks, voltage boosters, and inverters, making it economically feasible.
- **Environmentally Friendly Operation:** The inclusion of an air filtration unit helps reduce particulate emissions and improves the environmental performance of the system.
- **Simple Construction and Maintenance:** The system has a simple design with minimal moving parts, resulting in low maintenance requirements and improved reliability.
- **Suitable for Rural and Remote Areas:** The generated power can be used for low-power devices such as LED lighting in areas where access to electricity is limited.
- **Promotes Sustainable Development:** The project addresses two major challenges simultaneously plastic waste disposal and energy generation contributing to sustainable waste management practices.
- **Scalable Design:** The system can be further enhanced by using multiple TEG modules and improved heat recovery techniques to increase power generation.
- **Educational and Research Value:** The prototype serves as a practical demonstration of thermoelectric energy harvesting and waste-to-energy technology for academic and research purposes.

VII. DRAWBACKS

- **Low Energy Conversion Efficiency:** Thermoelectric generators convert only a small portion of thermal energy into electrical energy, limiting overall system efficiency.
- **Limited Power Output:** The prototype generates power in the milliwatt range, making it suitable only for low-power applications such as LEDs and small electronic devices.
- **Dependence on Temperature Difference:** The electrical output is highly dependent on the temperature gradient across the TEG. Lower temperature differences result in reduced power generation.
- **Heat Losses:** A significant amount of heat produced during plastic combustion is lost to the surroundings and is not converted into useful electrical energy.
- **Emission Concerns:** Although an air filtration unit is used, combustion of plastic waste may still release harmful gases and pollutants that require advanced emission control systems.
- **Voltage Fluctuations:** The generated voltage varies with changes in temperature, resulting in an unstable power output that may require additional voltage regulation.
- **Limited Scalability of Single TEG Module:** A single TEG module cannot produce sufficient power for large electrical loads. Multiple modules are required for higher energy generation.
- **Requirement of Continuous Heat Source:** Electricity generation is possible only while plastic waste is being combusted and a sufficient temperature gradient is maintained.
- **Maintenance of Combustion and Filtration Units:** The combustion chamber and air filter require periodic cleaning and maintenance for efficient operation.
- **Environmental and Safety Issues:** Improper combustion of plastic waste can lead to toxic emissions and safety hazards, necessitating careful monitoring and controlled operation.

CONCLUSION

This study proposed a novel waste-to-energy system utilizing a thermoelectric generator (TEG) to harness the excess heat energy produced during the combustion of plastic waste. While most TEG studies are qualitative, this study identified the electrical power output, current, and voltage to be positively correlated with the temperature differential, yielding an optimal power output of 372.4 mW at 110°C.

The novel waste-to-energy system addresses the three dimensions of sustainability (environmental, economic, and social) with the added benefit of the air filtration component. The system demonstrates the practicality of thermoelectric energy harvesting as an inexpensive, sustainable waste to energy system.

FUTURE SCOPE

Future focus areas include:

- The plastic waste-to-energy conversion system can work better if we use thermoelectric materials that can convert more energy.
- We can also make it work better by using thermoelectric generator modules together to make more power.
- In the future we can make it even better by using technologies to reduce bad emissions and help the environment.
- Using internet connected monitoring systems can help us see how the system is working in time and make it automatic.
- We can also try to make the system work better by finding ways to reuse heat and making the system bigger so it can be used in communities or industries.
- This can make the plastic waste-to-energy conversion system more practical and useful for people.

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