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Municipal Solid Waste Based Power Generation: A Case Study in Chittagong City

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***Abstract*—Non-conventional thermoelectric generation includes electricity using the heat salvaged from engine exhaust. Another technique is municipal solid waste-based power generation. This work evaluates the possibility of thermoelectric power generation from wastes in Chittagong city of Bangladesh. A massive amount of waste is produced daily in the town, which can be converted into heat energy to produce electricity. In this work, the amount of electricity generated from the waste in the city area is studied. The study includes data collection, data analysis, and a prototype model to ensure the proposed approach's prospect. The implemented prototype model is deployed on a smaller scale considering several aspects of the actual data. The simulation and implementation results ensure the potential of the study to be implemented on a bigger scale.**

***Index Terms*—thermoelectric energy, wastes, renewable energy, environmental issue, SDG7**

I. Introduction

In a Thermal System (TS), the heat energy is converted into electric power. The electricity-generating process's exceedingly high cost is reduced through non-renewable energy and delivers significant environmental effects. Since fossil fuels are non-renewable and require finite resources that are declining because of environmentally damaging retrieval technique, there are needs for non-conventional methods to reduce ongoing energy crises.

Numerous TS processes have been explored in the literature. Existing approaches can be broadly classified into thermal solar systems and waste to the power system. In a thermal solar system, the solar energy is converted into electricity through photovoltaic cells embedded in a solar panel. The maximum efficiency of cells is less than 35%, which is reported as the latest. There are numerous resistances to get the optimum efficiency. On the other hand, waste-based power generation delivers higher efficiency if handling in an optimum way. Numerous benefits can be achieved from waste-based power generation: delivers (i) a good waste management system, (ii) low-cost raw materials, (iii) environmentally friendly, and (iv) sustainable development goals. The main challenge of wast-based power generation is to propagate the Peltier effect to an observable output, which depends on TS's output, necessitating a particular impact or an optimum output. Identification of such efficient outcomes is challenging since the number of possible Peltier effects and variation of weather.

On the other hand, the research shows that about 42% of the population of Bangladesh has no access to electricity. The rest of the 58% people has a maximum demand of 10,390MW per day in which the daily peak demand and evening peak demand are 5,515 MW and 6,987 MW, respectively. However, the total capacity of electricity generation is about 8,709 MW which accounts for a deficit of 2081 MW [1]. Despite having such huge debts, only 3.3% of electricity is being generated by renewable sources [2].

Most importantly, for electricity generation effectively and efficiently, a proper source of heat needs to be ensured. Peltier effect can be a good choice by reducing the effect of heat leakage for weather variation. An optimum efficiency can generate a significant amount of electricity from TS. Electricity is generated through a heat sink placed in between two different temperature bodies. The hot body contains hot water, which sources the burning of wastes, and the cold junction is normal water-filled. The Peltier effect efficiently works between two different temperature junctions to produce an electric current through a wire with a voltage drop between two terminals.

In this work, we consider a threat model of electricity being generated from the heat produced by burning wastes in the municipal area. No vapor-based turbine is used in this work as a conventional thermal power plant does. The amount of wastes is calculated based on 30 days average in the municipal area. The projected heat generation is estimated through data analysis.

The proposed technique is based on a practical data analysis. The collected data is analyzed to apply appropriately in the Peltier engine to generate electricity. The power is generated by the Peltier element heated and cooled via aluminum profiles standing in two water baths of different temperatures (dT 60 deg). The generated power drives a small electric motor with a connected propeller. To be more precise, it delivers the Seebeck effect using Peltier elements. The Seebeck effect causes a voltage drop if two metals or semiconductor wires are connected to two different temperature ends. The different electron densities of the two materials result in diffusion and charge separation. The voltage drop is nearly proportional to the temperature difference of the junction.

Removal of energy in such a system is only possible when the other ends of the wires have a different temperature than

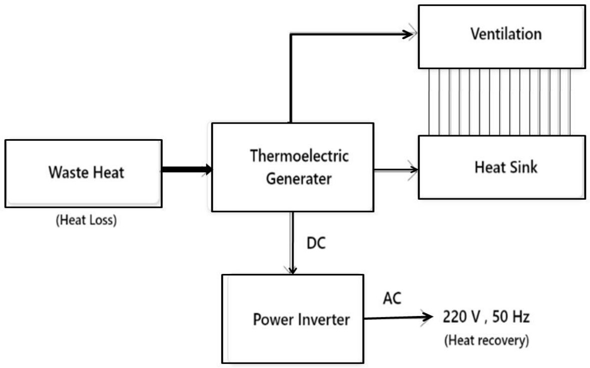


Fig. 1: Block diagram of a thermoelectric power Plant.

the junction. Otherwise, a voltage of the same amount is generated, and the initial voltage is annihilated when connecting an external load. The junction's heating yields a net voltage that can generate a current through a connected external load. So a part of the heat input to the junction is converted into electrical energy. The created voltage is of several microvolts per kelvin difference between the intersection and the other end. Several of these junctions connected in series in one is housing to form the thermal generator. It is constructed to increase the output voltage and integrate all junctions in a compact module with two surfaces for heat supply and cooling.

The rest of this paper is organized as follows. Section II introduces the energy conversion technologies. Section III presents an overview about related works. Section IV describes the data collection and analysis. Section V describes a prototype model. Section VI discusses the experimental results of the proposed electricity generation technique. Section VII concludes this paper by summarizing the key contributions and results.

II. Energy Conversion Technologies

A. Thermoelectric Power

A Thermoelectric power station is a power station where the heat energy is converted into electric power. Most of the places in this world use a steam-driven turbine. In the conventional thermal power plant, water is heated to turn it into steam and feeds to the turbine to create a rotating force, and an electrical generator [3]. Another way of generating electricity is heat sink technology which works with temperature differences of two junctions. A block diagram of this type of thermoelectric plant is shown in Fig. 1

B. Dish-Stirling System

A Stirling engine is a very efficient engine. Its efficiency range is about 30-40% resulting from a temperature range of 700-800 degrees Celsius, and operating speed is about 2000-4000 rpm [4]. Stirling engine works on the Stirling cycle.

C. Hydrothermal

Hydro-thermal destructive distillation is often outlined as combined dehydration and de-carboxylase lotion of fuel to lift its carbon content to achieve a better hot worth. It is realized by applying high temperatures (180â€“220Â°C) to biomass in an exceeding suspension with water below saturated pressure for many hours [5].

D. Incineration

Incineration means that the usually used waste for the conversion technology. Wastes square measure burnt to provide heat or biogas. Those heats may be used directly in industries or households; conjointly, heat may be accustomed to turning out electricity [6].

E. Landfill Gas

For disposal of municipal and home solid wastes or refuses, Land filling is the most used method. The natural degradation of MSW generates landfill gas (LFG). The created gas is often collected and used for various functions like electricity generation.

III. Proposed Approach

In the proposed work, a thermal power generation technique utilizing the Peltier effect is proposed based on heat sources from wastes. The source of heat is the burning of wastes collected daily from the Chittagong city municipal area. The data collection is carried out from the site and analyzed with all the feasibility of establishing a bigger scale plant to that city corporation zone. Based on the data analysis, a prototype model is implemented. A simulation-based study shows that data integrity and practical implementation ensure the proposed method's data validity.

The proposed thermal power generation system has environmental issues like air pollution through carbon emission to the atmosphere. Data analysis is done to identify ecological effects. The burning of solid wastes produces carbon dioxide gas. We may decrease the emitted carbon dioxide using some modern technologies. At an ordinary temperature, carbon dioxide is quite in-reactive so that it can be converted into carbon monoxide and oxygen. Above 1,700 °C (3,100 °F), it partially decomposes into carbon monoxide and oxygen. Hydrogen or carbon also converts to carbon monoxide at high temperatures. Ammonia reacts with carbon dioxide under pressure to form ammonium carbonate, then urea, an important component of fertilizers and plastics. Therefore, using some effective techniques, environmental pollution can be mitigated.

The efficiency of the proposed technique is significant and can be applied in numerous applications. The enhanced efficiency can enable the thermoelectric generator to operate in a low-temperature gradient so that energy can be harvested even from a low amount of wasted heat.

Electrical power is generated by a Peltier element heated and cooled via aluminum profiles standing in two water baths of different temperatures. The generated power drives a small electric motor with a connected propeller—a simple and accessible demonstration of the Peltier effect. To be more precise: it is a demonstration of the Seebeck using a Peltier element. The Seebeck effect is that a voltage is created if you connect two metals or semiconductors wires at one end: The different electron densities of the two materials result in diffusion and charge separation. A voltage is generated that is nearly proportional to the temperature of the junction. Removal of energy in such a system is only possible when the other ends of the wires have a different temperature than the intersection. Otherwise, a voltage of the same amount is generated, and the initial voltage is annihilated when connecting an external load. The junction's heating yields a net voltage that can generate a current through a connected external load. So a part of the heat input to the junction is converted into electrical energy. The created voltage is of several microvolts per kelvin difference between the junction and the other end. Several junctions connected in a series in one housing forms the thermal generator and are constructed to increase the output voltage and integrate all junctions in a compact module with two surfaces for heat supply and cooling.

IV. Related Works

Among other non-conventional methods of power generation, the thermo-electric process is a thriving one. Due to the usage of nanotechnology for building the thermoelectric modules, the figure of merit and efficiency are increased [7].

Thermoelectric Power is currently at different stages of commercialization. Various companies are adopting this method, and with some modifications in the process, it is on its way to becoming more natural. Besides, some renowned companies like Europlasma, Plasco Energy Group, and InEn Tec. have currently been conducting several pilot experiments. However, they have no commercial unit in operations, unlike Westinghouse, which has an entire scale facility and multiple projects completed and under construction in Japan, UK, and China [8].

Numerous techniques of thermoelectric power generation based on different geographical zones are in the literature. A parallel-plate heat exchanger is utilized to produce electricity from wastes [9]. Maximum power output is achieved by calibrating junction temperature. In [10], authors present a survey on waste to energy as a potential alternative source of energy and show the technique as economically viable and environmentally sustainable.

Municipal solid wastes with sewage sludge-based thermal power generation are presented in [11]. The environmental impacts in four different categories are described in detail. Municipal waste management and Waste-to-Energy potentials in New Zealand are discussed in [12]. Rather than landfill, authors show the generation of electricity is more economical. Authors in [13], show three different systems to generate electricity from wastes in Brazil. An economic analysis is performed with some key parameters to ensure the electricity generation is more economical than landfills.

Authors in [14], show a primary cooler using a COG heat pump is proposed to replace steam refrigeration. Rather than this, the primary cooler has a good prospect for broad application. A two-phase thermofluidic oscillator with regenerator is experimentation investigated. Which specializes in the mechanism of regenerator in lowering the onset temperature [15]. Authors show a reliable thermal model for a thermoelectric generator using a heat sink integrated with a thermal energy storage unit for solar reversible power generation of thermoelectric components [16].

TABLE I: Types of wastes in Chittagong city of Bangladesh

Waste	Daily (ton)	Year(Ton)
Kitchen waste	12200	4453000
Iron & wood	400	146000
Textile waste	2100	766500
Paper	700	255500
Poly	2100	766500
Industry	2200	803000
Food Waste	1200	438000

Therefore, different types of techniques are available in the literature with their various merits and demerits. In this work, a thermal power generation system is proposed from the perspective of Bangladesh. In this zone, to the best of our knowledge, no plant can utilize wastes to generate electricity.

V. Data Collection and Analysis

The proposed approach generates electricity using the Thermoelectric potential on wastes burning. Different types of waste are produced daily in Chittagong city, such as kitchen wastes, Iron and food wastes, textile wastes, paper wastes, poly waste, etc. In Table I, can be seen the different types of wastes produced daily in Chittagong city. Daily, approximately 20,900 tons of wastes are produced in the town. Therefore, monthly, 62,7000 tons of wastes are produced. With an estimation of generating 1.6 Watt power, it requires 1 Kg of wastes. Therefore, using 627000 tons of wastes, it can be approximated of generating ($627000000 \times 1.6 =$) 1003.20 MW power per month, so yearly can be generated 12038.4 MW.

VI. Proposed Waste Based Power Generation

Combusting wastes produce heat. The generated heat can be used directly in industry or residence. In addition, heat can be transformed into another form of energy such as electricity. Combustion can be done in several ways. Mass burn combustion is a way where wastes are directly combusted without any derivation. Refuse Derived Fuel (RDF) is another way where recyclable wastes are sorted from the rest. Using the thermal potential of wastes, the proposed technique generates electricity. Thermoelectric coolers (TEC or Peltier) produce a temperature differential on both sides. One aspect gets hot, and also the different part gets cool. Therefore, they are not to either heat one thing up or cool one thing down, reckoning on that aspect it utilizes. The Peltier works as long as it takes away the warmth from the new aspect. When turning on the device, the new aspect can heat quickly, the cold aspect can cool quickly. Therefore, using this temperature difference, electricity is generated thermally from wastes. The flow diagram of the proposed approach is shown in Fig. 2.

Electrical power is generated by a Peltier element heated and cooled via aluminum profiles standing in two water baths of different temperatures (60 degrees). The generated power

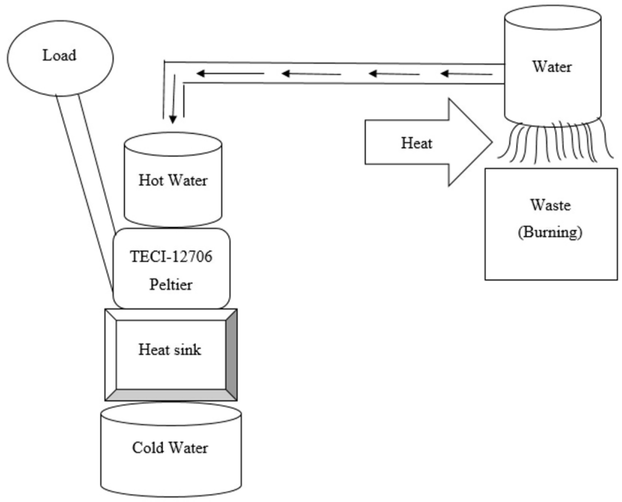


Fig. 2: Workflow Diagram of the proposed thermoelectric plant.

drives a small electric motor with a connected propeller. It applies the Peltier mechanism utilizing the Seebeck effect. A voltage is generated that is nearly proportional to the temperature of the junction. The junction's heating yields a net voltage that can generate a current through a connected external load. So a part of the heat input to the junction is converted into electrical energy. The general equation of generating power from wastes is Power=Voltage X Current.

The proposed prototype model consists of a thermoelectric cooler (Peltier), an Aluminum heat sink, and a miniature low torque flat DC motor. The complete model is shown in Fig. 2.

A. Design of Proposed Model

Thermal power generation based on the in-field survey of the TS plant, different parameters are considered such as thermal cooler, heat sink, miniature low torque flat dc motor, multimeter, jumper wire, and aluminum water container. The proposed model is also designed in Matlab Simulink with the specifications of analyzed data. Fig. 3 displays the proposed prototype model.

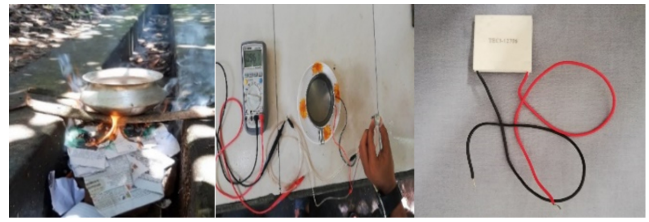
B. Mathematical Model

In the proposed thermal system design, electricity is generated by a Peltier element heated and cooled via aluminum profiles standing in two water baths of different temperatures. The different electron densities of the two-material result in a diffusion and charge separation. A voltage is generated that is nearly proportional to the temperature of the junction. The junction's heating yields a net voltage that can generate a current through a connected external load.

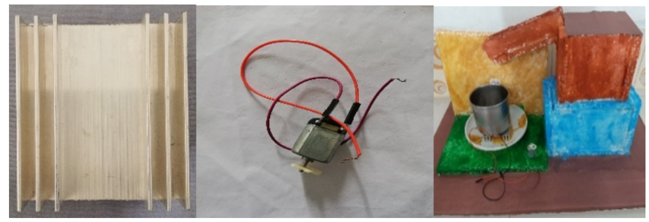
VII. Results

A. Simulation Result

For efficiency calculation of Bi2Te3, the calculated efficiency was 5.936% for a temperature difference 369^0C, and power calculated for each pallet was 0.3807 W. For the efficiency calculation of Si0.7Ge0.3, the calculation shows 7.906% of efficiency at 379^0C (652K), and the power produced from each pallet is 41.48 W. Simulation results are shown in Fig. 4.



(a)



(b)

Fig. 3: The Prototype model of the proposed approach: (a)Boiling water, measuring voltage output and Thermoelectric Cooler (Peltier), (b) aluminum heat sink, miniature low torque flat dc motor, and model of waste to energy conversion by thermoelectric power.

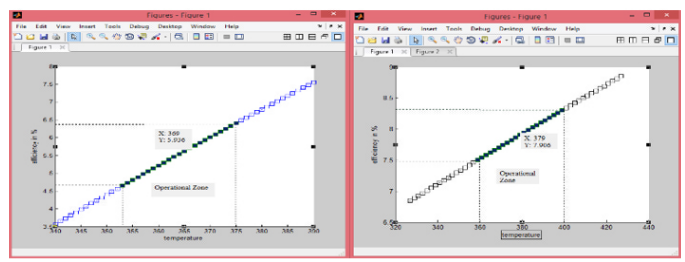


Fig. 4: Bi2Te3 efficiency curve and Si0.7Ge0.3 efficiency curve.

B. Implementation Result

In our work, we have used about 1kg of waste for heating half liter water. This estimation is done for 1 TECI-12706 Peltier module.

• It can be work in between 68°-138° Celsius temperatures.

• It can generate a maximum of 63W.

• When the hot side temperature of the Peltier is 25°, then it can generate 50W. In this case, the voltage is around 14.4V.

• When the hot side temperature of the Peltier is 50°, then it can generate 57W. In this case, the voltage is around 16.4V.

By doing our thermoelectric experiment using the TECI-12706 Peltier module, we got the voltage around 1V, or 1000 mV (Actually, 0.961 Voltage), and the current was 1.6mA. Using 1 kg waste, 1 TECI-12707 Peltier, half-liter hot water, we got 1.6W output power. In a day, about 20,900 tons of waste is produced in Chittagong. 20,900 tons = 20,900,000 kg, so by using 20,900,000 kg waste, we can generate (20,900,000 × 1.6) =33,440,000 W/ day. If we convert it into MW, we can generate 1.4 MW daily. In a month, we can generate 42 MW using thermal system.

VIII. Conclusion

This work showed a potential scope for establishing a waste-based thermoelectric power generation in Bangladesh. The gradual degradation of fossil fuels pushes the government to increase renewable energy generation and demand clean energy from customers and businesses. Thermoelectric can be a substantial potential option for this purpose. We hope that further research with appropriate funding options may open a significant opportunity to implement this project on a large scale. Even though there is no widely used evidence of conversion potential and practical applications of the discussed methods, more efforts should be devoted to materializing research, structure optimization, and commercialization.

Acknowledgment

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