

Organic Waste to Electricity Conversion

1st Aleena B S

Assistant professor

Department of Electrical Engineering
College of Engineering, Attingal,
Thiruvananthapuram, Kerala, India

2nd Muhammed Jeffrin N

B.Tech scholar

Department of Electrical Engineering
College of Engineering, Attingal,
Thiruvananthapuram, Kerala, India

Abstract—The "Organic Waste to Electricity Conversion" project presents a sustainable solution to energy generation by utilizing organic waste as a renewable resource. This project harnesses the heat produced from burning organic matter to generate electricity, using Thermoelectric Generators (TEGs) that convert thermal energy directly into electrical power. A critical component of the system design includes an efficient heat transfer mechanism, supported by cooling modules to maintain a temperature gradient across the TEGs, thereby optimizing power output. Through this process, the system not only generates clean energy but also contributes to waste management by reducing organic waste accumulation. Targeted for small scale applications, particularly in rural and resource-limited environments, this project explores the feasibility, efficiency, and environmental impact of converting waste to energy, providing a viable alternative to traditional power sources and supporting the push for eco-friendly and self-sustaining energy solutions. The project further investigates the adaptability of thermoelectric technology in real-world applications, highlighting its potential to produce electricity at minimal operational costs and with low maintenance requirements. By transforming everyday organic waste into a valuable energy resource, this system fosters both environmental sustainability and energy independence. Ultimately, this project aims to create a scalable model that could benefit off grid communities, reduce landfill contributions, and encourage a circular economy approach to energy and waste management. [1]–[3]

I. INTRODUCTION

The "Organic Waste to Electricity Conversion using Thermoelectric Generators (TEGs)" project presents an innovative approach to addressing the intertwined global challenges of energy scarcity and waste management by utilizing organic waste as a renewable energy source. With the rising demand for clean and sustainable energy solutions, particularly in rural and off-grid areas where conventional power infrastructure is limited or inaccessible, this project taps into the potential of thermoelectric technology to produce electricity from the heat generated by burning organic waste. Thermoelectric generators operate on the Seebeck effect, where a temperature difference across a material generates an electric voltage, converting thermal energy directly into electrical power without requiring any moving parts—making TEGs both durable and low-maintenance, ideal for long-term use in sustainable systems. By combining TEG modules with an efficient heat transfer mechanism, this project maximizes the conversion of waste heat to electrical power through strategic design, incorporating cooling elements that enhance the necessary

temperature gradient across the TEGs to optimize output. The system is designed to be simple yet effective, aimed at small-scale applications that can be particularly beneficial in remote communities, where it not only offers a reliable power source but also addresses the pressing issue of organic waste disposal. By turning waste into a resource, this project promotes environmental sustainability, reduces dependency on traditional energy sources, and provides a model for an affordable, low-maintenance, and renewable power solution. Furthermore, the project's alignment with sustainability goals underscores its broader potential for adaptation in diverse settings, fostering a circular approach to waste and energy that can benefit both local communities and the environment as a whole. [4]

II. LITERATURE SURVEY

"Organic Waste to Electricity Conversion" explores the range of methodologies and technologies developed to harness energy from organic waste, examining the scientific advancements and ongoing challenges within the field. Over the years, a significant body of research has focused on transforming organic waste—such as agricultural residue, food scraps, and biomass—into viable energy sources, aiming to address both energy needs and waste management challenges. Initial approaches to organic waste conversion primarily involved direct combustion, anaerobic digestion, and gasification. Studies have shown that each of these methods offers unique benefits and limitations depending on the type of waste, local environmental conditions, and economic factors. For example, anaerobic digestion has been widely adopted in agricultural settings where animal manure and crop residue are readily available, producing biogas that can be used directly for heating or electricity generation. Despite these advantages, biogas systems require controlled conditions and can be expensive to set up, which has limited their applicability in low-income regions. Recent literature highlights advancements in gasification and pyrolysis as alternative methods to convert organic waste into electricity. Gasification involves converting organic materials into syngas—a mix of hydrogen, carbon monoxide, and other gases—through a high-temperature, oxygen-limited process. Studies by Panwar et al. (2012) indicate that syngas can be efficiently combusted in engines or turbines for electricity generation, making it a promising solution for areas with abundant biomass resources. However, one challenge identified

by recent studies is the complexity and cost of gasification systems, which often require precise control mechanisms and specific conditions to operate efficiently. Research by Janajreh et al. (2013) explored methods to improve gasification efficiency through feedstock pre-treatment, which enhances the energy yield but also adds operational costs. Despite the technical challenges, gasification has gained attention as a cleaner alternative to traditional incineration, as it produces fewer pollutants and has a higher energy conversion efficiency. In addition to gasification, pyrolysis has emerged as another promising technology for organic waste-to-energy conversion. Pyrolysis decomposes organic materials at high temperatures in the absence of oxygen, producing bio-oil, syngas, and biochar. Several studies have focused on optimizing the pyrolysis process to maximize energy output and improve environmental outcomes. Researchers like Bridgwater (2012) have demonstrated the potential of pyrolysis to generate bio-oil, which can be refined into transportable fuel or used on-site for power generation. Pyrolysis offers the advantage of producing biochar as a by-product, which can improve soil fertility and sequester carbon, making it environmentally beneficial. However, studies indicate that pyrolysis systems require significant energy input for pre-heating and precise temperature control, raising questions about their energy balance and economic feasibility in small-scale applications. Nevertheless, recent advancements in catalytic pyrolysis and microwave-assisted pyrolysis are being explored to enhance energy efficiency and make the technology more adaptable to various types of organic waste, as highlighted by Czernik and Bridgwater (2004).

A key theme is the integration of these organic wasteto-electricity technologies within decentralized, small-scale systems, particularly for use in rural or isolated communities where access to grid electricity is limited. Researchers such as Kumar et al. (2017) have reviewed the socio-economic impacts of small-scale waste-to-energy plants, noting that while these systems contribute to energy independence and local sustainability, they often face challenges in terms of community acceptance, maintenance, and economic viability. Communitybased biogas plants, for instance, have been widely adopted in India and Nepal, showing promise in supporting rural livelihoods. However, studies also reveal operational challenges such as maintaining continuous waste supply, managing waste composition variability, and ensuring consistent operation, which can affect the reliability of these systems for electricity generation. Current literature underscores the importance of designing waste-to-energy solutions that are adaptable to local conditions and include social dimensions, ensuring long-term sustainability.

III. PROJECT OBJECTIVES

The main objective of this project is to develop a system that can convert organic waste into useful electrical energy, thereby addressing both energy generation and waste disposal challenges in an eco-friendly and cost-effective way. To design a system capable of generating electricity from the heat

produced by burning organic waste, utilizing thermoelectric technology.

1. To create a sustainable method for managing organic waste, transforming it from a disposal problem into a valuable source of energy.

2. To demonstrate an alternative source of clean energy that can reduce dependence on conventional electricity sources, especially in rural or off-grid areas.

3. To showcase the practical application of thermoelectric generators (TEGs) in converting thermal energy to electrical energy through simple and affordable engineering design.

4. To analyze the efficiency and feasibility of small-scale organic waste-to-electricity conversion, identifying the potential for community-level or domestic implementation.

5. To highlight future possibilities of integrating such systems into waste management and renewable energy solutions, promoting sustainable living and energy conservation.

IV. SYSTEM DESIGN AND METHODOLOGY

The system is designed with the primary goal of converting organic waste heat into useful electrical energy through the use of thermoelectric generators (TEGs). The core design approach focuses on harnessing the Seebeck effect, where a temperature difference across the TEG modules generates a voltage. The system comprises a base combustion chamber for controlled organic waste burning, a heat transfer mechanism to efficiently channel the heat to the hot side of the TEGs, and a cooling system to maintain the necessary temperature gradient by dissipating heat from the cold side. To optimize energy generation, the design also incorporates a buck converter circuit to stabilize and regulate the variable output from TEGs for practical use, such as charging batteries or running lowpower devices. Proper insulation and wire mesh enclosures are considered to enhance system stability and safety during operation. [5]

The methodology followed in the project includes several stages, starting from material selection, component integration, thermal management planning, to system assembly and testing. Initially, thermoelectric modules were arranged in series to achieve a higher combined voltage output. Aluminum alloy sheets and thermal pastes were used to ensure uniform heat transfer and distribution across the TEG surfaces. The cooling mechanism was designed with Aluminium water cooling blocks to efficiently draw heat away from the cold side. The overall structure was framed with stainless steel wire mesh and support bolts to provide mechanical stability while allowing airflow. The system's performance was evaluated through experimental trials to monitor voltage output, heat retention, and cooling efficiency, allowing refinements in component placement and material usage for better results. [4]–[6]

V. WORKING PRINCIPLE

The fundamental working principle of this system is based on the Seebeck effect, a thermoelectric phenomenon where a temperature difference across two sides of a thermoelectric generator (TEG) produces a direct voltage. When the hot side

of the TEG is exposed to high temperatures generated from burning waste, and the cold side is kept relatively cool using a dedicated cooling mechanism, the TEG modules generate an electric potential. These solid-state devices have no moving parts, making them highly reliable for direct thermo-to-electric conversion. The magnitude of voltage generated is directly proportional to the temperature gradient maintained across the TEG's surfaces. By connecting multiple TEG modules in series, we are able to achieve a cumulative voltage sufficient to power small loads or charge batteries. The use of efficient heat dissipation techniques on the cold side is critical to sustain this temperature difference, ensuring stable and continuous electricity generation.

The overall system is designed to effectively capture and utilize the heat energy produced from burning various forms of organic and paper waste. The waste is placed in a base plate surrounded with stainless steel wire meshes, where it is burned to produce high temperatures that are directly transferred to the hot side of the TEGs via a heat-transferring Aluminium alloy sheet. Simultaneously, the cooling system—consisting of Aluminum water cooling blocks, water flow and a pump ensures the cold side of the TEG remains at a much lower temperature, enhancing the efficiency of energy conversion. The generated voltage is then regulated using a buck converter circuit, which ensures a steady output voltage suitable for storage or direct usage. The entire system is enclosed within a wired mesh frame for safety, airflow, and structural integrity. This integrated approach enables simultaneous waste disposal and renewable electricity generation, providing a sustainable and practical solution for energy recovery from waste materials. [6]–[8]

VI. IMPLEMENTATION TECHNIQUE

The system was implemented with careful design and material selection to achieve efficient heat-to-electricity conversion. The combustion chamber was constructed using a high-temperature-resistant metallic base plate, enabling the burning of waste materials such as paper and dry leaves while ensuring uniform heat transfer to the thermoelectric generator (TEG) modules. Aluminum alloy sheets were used to enhance heat conduction to the hot side, while a wire mesh frame provided structural support, airflow, and operational safety. Thermal insulation was applied to minimize heat loss and maintain a concentrated heat source. [9]–[12]

To sustain the required temperature gradient, aluminum cooling blocks were attached to the cold side of the TEG modules for effective heat dissipation. The fluctuating electrical output from the TEGs was regulated using a buck converter to provide a stable voltage for storage or direct use, with modules connected in series as needed. The system was experimentally optimized by adjusting combustion conditions, airflow, and safety features. This prototype demonstrates a practical and scalable approach for integrating waste management with energy recovery.

The whole system can be divided into 4 key parts:

1. Thermoelectric Generator (TEG) Assembly : The core of our system consists of 24 thermoelectric generator (TEG) modules connected in series to maximize voltage output. These TEGs are sandwiched between two aluminum sheets for optimal heat transfer — with a 3 mm thick sheet on the hot side and a 2 mm thick sheet on the cold side to maintain structural integrity and effective conduction. The entire TEG assembly is securely suspended using M10 rods, which provide a stable frame while allowing space for the heat and cooling systems to function around the TEG setup.

2. Hot Side Construction : The hot side of the system is designed to create a focused heat source for the TEGs. A thick metallic base plate acts as the main heat source platform, which directly conducts heat to the TEG modules. Surrounding this base, stainless steel wire meshes are used to contain the burning material such as paper or organic waste while allowing sufficient airflow for consistent combustion. This structure ensures that the TEGs receive a stable and uniform heat supply.

3. Cold Side Cooling Mechanism : To maintain the necessary temperature gradient across the TEGs, a cold side cooling system is employed. This includes aluminum water cooling blocks attached to the cold side aluminum sheet. Water hoses are connected to these blocks, creating a closed-loop system with a pump to circulate water continuously. This setup effectively dissipates heat from the cold side, helping to maintain the temperature difference that drives electricity generation.

4. Output and Power Management : The electrical output generated by the TEG array is unstable due to fluctuating heat sources, so a buck converter is used to regulate and stabilize the output voltage. The buck converter allows the system to step down and smoothen the voltage, making it suitable to charge batteries or directly power small DC loads. This ensures that the energy harvested from waste combustion can be practically utilized for real-world applications.

VII. COMPONENTS

1. Thermo-Electric Modules (SP1848 SA 27145)

The SP1848-27145 SA thermoelectric generator (TEG) modules are compact solid-state devices that convert heat directly into electrical energy using the Seebeck effect. Composed of p-type and n-type semiconductor elements, they generate voltage when subjected to a temperature gradient. Owing to their lightweight structure, absence of moving parts, and reliable performance, they are well suited for small-scale energy harvesting applications.

In this system, a total of 28 TEG modules were utilized, with 24 connected in series to enhance the output voltage. These modules efficiently operate under moderate temperature differences, making them suitable for compact waste-to-energy conversion. Their small size, cost-effectiveness, and efficiency make them a key component of the proposed setup.

2. Aluminium Alloy Sheets

Aluminum alloy sheets were used as the primary thermal interface for the thermoelectric modules due to their high thermal conductivity (205 W/m-K), lightweight nature, and

corrosion resistance. Two sheets of different thicknesses were employed: a 3 mm sheet on the hot side to withstand high temperatures and ensure uniform heat distribution, and a 2 mm sheet on the cold side to facilitate efficient heat dissipation.

The hot-side sheet enhances structural stability and evenly transfers heat from the combustion source, while the thinner cold-side sheet improves contact with cooling blocks and supports rapid heat removal. This arrangement helps maintain an effective temperature gradient across the TEG modules, thereby improving power generation efficiency and overall system performance.

3. Aluminum Water Cooling Blocks

Aluminum water cooling blocks were employed to maintain a low temperature on the cold side of the thermoelectric modules. Fabricated from high-conductivity aluminum (205 W/m-K), these blocks contain internal channels that allow continuous water flow, enabling efficient heat absorption and dissipation. Direct contact with the TEGs, enhanced by thermal paste, ensures effective heat transfer and supports the maintenance of a significant temperature gradient.

A closed-loop cooling system, driven by a submersible pump, circulates water through the blocks via inlet and outlet connections. This arrangement maintains the cold-side temperature within an optimal range, thereby improving voltage and power output. The cooling system, combined with the heat source, ensures a stable temperature difference for consistent and reliable energy generation.

4. Stainless Steel Wire Mesh

A stainless steel wire mesh was used as the combustion chamber on the hot side, providing both structural support and efficient airflow for burning organic waste. Its high melting point, heat resistance, and durability make it suitable for sustained high-temperature operation. The open grid design facilitates adequate oxygen supply, ensuring efficient combustion and uniform heat distribution to the hot-side aluminum plate.

Typically made from SS304/SS316, the mesh offers excellent oxidation resistance and mechanical strength under thermal stress. It is securely mounted on the base plate and reinforced for stability during operation. The porous structure prevents ash accumulation while maintaining consistent combustion temperatures, thereby supporting a stable heat source for effective thermoelectric energy generation.

5. Buck Converter (DC 9V-120V to 12V 3A Step Down Module)

A DC-DC buck converter was employed to regulate the fluctuating electrical output from the thermoelectric modules (TEGs). As the TEG output varies with temperature gradient and load conditions, the converter steps down and stabilizes the voltage to a usable level for powering loads or energy storage, ensuring practical applicability of the system.

The converter operates over an input range of 9–120 V and provides a regulated output (typically 12 V) with high conversion efficiency. It also incorporates protection features such as overcurrent protection, thermal shutdown, and short-circuit protection, enhancing system reliability and safety.

6. Thermal Paste Thermal paste (heat sink compound) was applied between the thermoelectric modules (TEGs) and aluminum plates to enhance heat transfer by eliminating microscopic air gaps and surface imperfections. This improves thermal contact, enabling efficient heat flow across both hot and cold interfaces and maintaining a higher temperature gradient, which is critical for maximizing TEG output.

The paste, selected for its high thermal conductivity (above 4.5 W/m-K) and temperature stability, reduces interfacial thermal resistance and maintains performance under repeated thermal cycles. Its use is essential for optimizing the Seebeck effect and overall system efficiency.

7. M10 Rods

M10 rods were used as structural fasteners to provide mechanical support and maintain precise alignment of the system components, including aluminum plates, TEG modules, and cooling blocks. They ensure uniform clamping pressure across the TEG stack, which is essential for effective thermal contact and efficient heat transfer.

With high tensile strength and corrosion resistance, the 10 mm diameter rods can withstand thermal and mechanical stresses without deformation. The use of standard nuts and washers enables secure assembly and adjustable spacing, ensuring stability and consistent performance under operating conditions.

VIII. FABRICATION

Step 1 : TEGs Assembly and Soldering :

- Selection of 24 SP1848-27145 TEGs.
- Sandwiched between two aluminum plates (3 mm and 2 mm thick).
- Aligned and soldered them in series.
- Applied heat sink paste for sticking it to aluminium sheet and for thermal conductivity.
- Applied kapton tape to protect the system from short circuits.

Step 2 : Cold Side Implementation :

- Attachment of aluminum water cooling blocks to the aluminum alloy sheets by using thermal paste.
- Connection of cooling blocks and hose.
- Ensured working of pump and connected with hose.
- Ensuring leak-proof design.

Step 3 : Hot Side Design and Fixing :

- Fixing of base metallic plate and stainless steel wire mesh for burning organic waste.
- Cut down and connected wire mesh as per the required dimensions.
- Designing the support structure using M10 rods for holding everything stable.

IX. RESULTS AND ESTIMATION

The performance of the proposed waste-to-energy system was evaluated based on the calorific value of the fuel and the conversion efficiency of the thermoelectric generators (TEGs). Paper and dry organic waste, with an average calorific value of 15–16 MJ/kg, provide a viable low-grade heat source

for thermoelectric conversion. Considering a practical TEG efficiency of approximately 4% under operating temperature gradients, the theoretical electrical energy output from 1 kg of waste is estimated to be around 0.6 MJ (166.67 Wh). However, accounting for real-world losses such as incomplete combustion, thermal dissipation, and contact inefficiencies, the system achieves approximately 70% of the theoretical output. This results in a practical energy yield of about 116.67 Wh per kilogram of dry waste. These findings highlight the feasibility of the system for small-scale energy recovery, while also indicating the impact of thermal losses and system design on overall efficiency. Further improvements in insulation, heat transfer optimization, and temperature gradient maintenance could enhance the energy conversion performance.

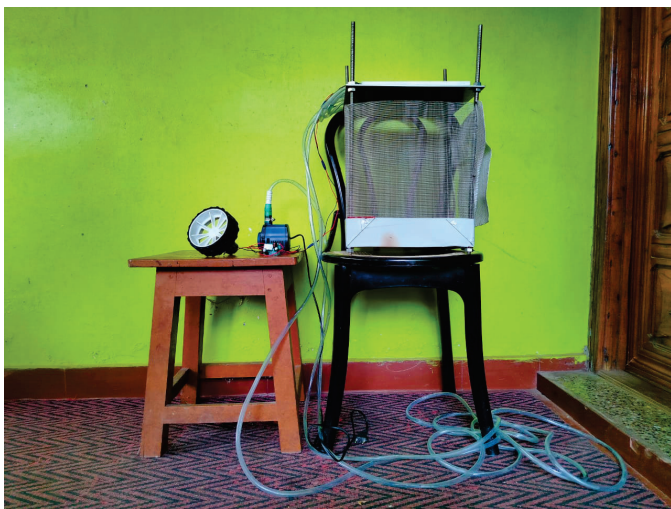


Fig. 1. Final Product

X. FUTURE SCOPE

- Improving the efficiency of TEG modules to convert more heat into electricity, which will significantly increase the system's output.
- Integration of automatic feeding and controlled combustion systems to ensure continuous burning and stable power generation without manual intervention.
- Development of better cooling systems on the cold side of TEG modules to maintain higher temperature differences and improve performance.
- Utilizing mixed types of waste, including agricultural and industrial waste, to diversify the input material and optimize energy production.
- Scaling up the system for community-level applications, such as small villages or local markets, to handle larger quantities of waste and produce more power.
- Incorporation of energy storage systems, like batteries and capacitors, to store the generated electricity for later use and make the system more practical.
- Design improvements to make the system compact and portable, so it can be used for disaster relief operations or in remote areas.

XI. CONCLUSION

This work demonstrates a sustainable approach for converting organic and dry waste into electrical energy using thermoelectric generators (TEGs). By utilizing heat from waste combustion, the system generates usable power without dependence on conventional fuels. Although the output is limited by the relatively low efficiency of TEGs, the system can still supply sufficient energy for low-power applications such as battery charging and small electronic devices. In addition to energy generation, the approach contributes to effective waste management, addressing two critical challenges simultaneously.

With advancements in TEG materials, improved thermal management, and optimized system design, the overall efficiency and power output can be enhanced. The system has potential for deployment in rural or off-grid areas where waste accumulation and energy scarcity coexist. Thus, it represents a scalable, low-cost, and environmentally friendly solution for integrated waste-to-energy conversion.

REFERENCES

- [1] Panwar, N. L., Richa Kothari, and V. V. Tyagi. "Thermo chemical conversion of biomass—Eco friendly energy routes." *Renewable and Sustainable Energy Reviews* 16.4 (2012): 1801-1816.
- [2] Janajreh, Isam, Idowu Adeyemi, and Sherien Elagroudy. "Bioreactor landfilling: operations, benefits and prospects." *Int. J. of Thermal & Environmental Engineering* 5.2 (2013): 175-181.
- [3] Yang, Yang, et al. "A techno-economic analysis of energy recovery from organic fraction of municipal solid waste (MSW) by an integrated intermediate pyrolysis and combined heat and power (CHP) plant." *Energy Conversion and Management* 174 (2018): 406-416.
- [4] Czernik, Stefan, and Anthony V. Bridgwater. "Overview of applications of biomass fast pyrolysis oil." *Energy & fuels* 18.2 (2004): 590-598.
- [5] Dhar, Hiya, Sunil Kumar, and Rakesh Kumar. "A review on organic waste to energy systems in India." *Bioresource technology* 245 (2017): 1229-1237.
- [6] Miramontes-Martínez, Luis Ramiro, et al. "Potential of electricity generation by organic wastes in Latin America: A techno-economic-environmental analysis." *Biomass Conversion and Biorefinery* 14.21 (2024): 27113-27124.
- [7] Raja, Vijayakumar, et al. "Electricity production using food waste: a review." *Environmental Chemistry Letters* 21.2 (2023): 839-864.
- [8] Maarif, Syamsul, et al. "Waste-to-energy development using organic waste recycling system (owrs): A study case of giwangan market." *International Journal of Renewable Energy Research (IJRER)* 9.1 (2019): 354-362.
- [9] Kacprzak, Andrzej, and Renata Włodarczyk. "Utilization of organic waste in a direct carbon fuel cell for sustainable electricity generation." *Energies* 16.21 (2023): 7359.
- [10] Zueva, Svetlana, et al. "Review of organic waste-to-energy (OWtE) technologies as a part of a sustainable circular economy." *Energies* 17.15 (2024): 3797.
- [11] Cudjoe, Dan, Myat Su Han, and Aditya P. Nandiwardhana. "Electricity generation using biogas from organic fraction of municipal solid waste generated in provinces of China: Techno-economic and environmental impact analysis." *Fuel Processing Technology* 203 (2020): 106381.
- [12] Dhiman, Saurabh Sudha, et al. "Producing methane, methanol and electricity from organic waste of fermentation reaction using novel microbes." *Bioresource Technology* 258 (2018): 270-278.