THIS ARTICLE IS CURRENTLY IN FORMATTING.
THE FINALIZED PDF WILL BE UPLOADED AS SOON AS IT IS READY

International Journal of Environmental Chemistry
Volume- 11, Issue- 02, Year- 2025
Research Article
Received Date: November 26, 2025
Accepted Date: December 31, 2025
Published Date: December 31, 2025

Transforming Waste Materials into Electrical Energy

[1]Assistant Professor, Jay Bahadur Singh, Department of Electrical Engineering, B.I.E.T. Lucknow B.I.E.T., LUCKNOW, Email: jay.electrical08@gmail.com
[*2]Student, Anurag Dixit, Department Of Electrical Engineering, B.I.E.T., LUCKNOW, Email: dixitanurag2003@gmail.com

1. Abstract

Due to the growing issue of waste management and the rising request for energy worldwide, there is a lot of interest in using waste materials for production of electricity. Paper waste, which includes rejected paper goods and industrial byproducts, offers a practical and sustainable alternative to other waste materials. Feedstock for the generation of energy. This paper examines various techniques for producing electricity from paper waste, such as combustion, gasification, pyrolysis, and biogas generation through anaerobic digestion. The study investigates multiple approaches to converting paper waste into electrical energy, including burning, gasifying, pyrolyzing, and creating biogas via anaerobic processes. This work analyzes different paper-waste-to-energy methods—combustion, gasification, pyrolysis, and anaerobic biogas production.. Every approach has a extraordinary set of benefits and negatives concerning effectiveness, environmental impact, and financial viability. Although direct combustion is the most straightforward technique, gasification and pyrolysis provide greater efficiency and reduced emissions. When paired with organic waste, biogas production offers a renewable energy source with further advantages like waste reduction and nourishment production. In spite of the probable, there are still major difficulties to extensive approval, including high primary investment costs, waste sorting necessities, and technological complexity. However, the satisfactory future of paper waste as a basis of renewable energy is emphasized by current developments in waste-to- energy technologies and an increasing focus on sustainability and circular economy principles. This review emphasizes the need for extra study and development to expand these technologies usefulness, affordable, and environmental performance for dominant exercise.

Keywords: Heating panels, resistors, capacitors, IN4007, LED lights, Zaar boxes, and 4.5V batteries.

2. Introduction

Several waste-to-energy facilities have been constructed in India to generate electricity. Waste-to-energy (WTE) facilities generate power by incinerating dry, combustible materials—such as municipal solid waste (MSW) with a calorific value above 1500 Kcal/kg. To meet the emission standards set under the Solid Waste Management Rules of 2016, these plants are equipped with pollution-control systems that limit pollutants released from MSW combustion. They also use Online Emission Monitoring Systems, which are supervised by the State Pollution Control Boards (SPCBs). Across urban India, approximately 38 billion gallons of sewage and 55 million tons of municipal solid waste are generated each year. Industries also generate large amounts of liquid and solid waste. The goal of this research project is to create electric energy from waste, rubber, plastic, and other materials, store that energy in a battery via a circuit, and use the entire working model. Between 1% and 1.3% more waste will be produced annually per person in India. This issue greatly reduces the amount of land that can be used. It also influences the need for disposal space, the cost of collecting and transporting waste, and the environmental effects of advanced municipal solid waste (MSW) technologies. Waste paper can be burned in modern, high-efficiency boilers designed for recoverable fiber or in older boilers that use coal, wood waste, or both. The resulting energy can replace fossil fuels in pulp and paper mills as well as other commercial or industrial operations. Through cogeneration, any surplus electricity can be sold back to the grid, reducing the need for extra fossil fuel consumption [1].

Although total energy use may not decline, this approach prioritizes renewable biomass over non-renewable energy sources, helping to cut emissions of carbon dioxide (CO_2), sulfur oxides, and volatile organic compounds. In this project, we demonstrate an efficient method for converting waste materials into electrical energy. We also explain how to integrate a pollution-control filter into the model to effectively reduce emissions. After completing the model, we evaluate its performance and confirm its efficiency in producing electricity from waste.

By lighting an LED bulb and using filters to minimize pollution from power generation, our project successfully shows how waste can be turned into electricity and stored in batteries. This process produces renewable energy while reducing landfill disposal. It also helps lower greenhouse gas emissions by preventing methane release, which occurs when waste decomposes in landfills.

3. Literature Review-:

Growing global concerns about waste management and the demand for sustainable energy solutions have accelerated the development of technologies that produce electricity from unused materials. Waste-to- Energy (WTE) is a process that provides an eco-friendly additional for conventional waste disposal and energy production methods. The primary technologies, feedstocks, environmental effects, and difficulties related to producing electricity from waste are outlined in this review of the literature [2].

3.1 Overview of Waste-to-Energy (WTE) Technologies

Waste-to-Energy (WTE) is the process of turning non-recyclable waste materials into energy that can be used, like fuel, heat, or electricity. The following are the main WTE technologies:.

a) Incineration

Waste materials are burned at high temperatures during incineration to generate heat, which steam turbines then use to generate electricity. This method is among the oldest and most widely used techniques for converting waste into electrical energy. Burning municipal solid waste (MSW) can cut its volume by as much as 90% while producing electricity, as noted [3].

b) Anaerobic Digestion

In the biological process called anaerobic digestion (AD), microorganisms decompose organic materials without the presence of oxygen, generating biogas that is typically rich in methane. This biogas can be used in gas engines or turbines to produce electricity. Emphasize the role of AD in creating renewable energy from sources such as food waste, agricultural by-products, and sewage sludge. AD also provides significant benefits in reducing greenhouse gas emissions, especially methane released from landfills [4].

c) Gasification

Gasification converts organic material into synthetic gas (syngas) by exposing it to high temperatures and controlled, low-oxygen conditions. The resulting syngas—composed of carbon monoxide, hydrogen, and methane—can be utilized in internal combustion engines or gas turbines to produce electricity. Recognized that gasification is a decent method for generating energy from a wide spread dissimilarity of feedstocks, with biomass and unused plastics [5].

3.2 Waste Materials Used in Electricity Generation

The kind of waste material utilized has a significant impact on WTE technologies' effectiveness. Optimizing the energy recovery process requires an understanding of the material properties, and different waste streams are appropriate for different technologies. Typical feedstocks consist of:

a) Municipal Solid Waste (MSW)

MSW encompasses paper, plastics, metals, organic matter, and various wastes from households, businesses, and industries. It is the most commonly used type of waste in WTE systems, particularly in incineration and gasification processes. Energy recovery may be impacted by the wide variations in MSW's calorific value. To increase efficiency, waste may need to be sorted and preprocessed [6].

b) Plastics

Plastics are increasingly known as a valuable unused resource due to their high energy content. Highpoints how unused plastics can be used in gasification and pyrolysis to generate syngas or other useful fuels. But how plastics are disposed of affects the environment, particularly in terms of how long plastic waste remains in the environment [7].

c) Food and Agricultural Waste

Anaerobic digestion systems frequently use organic materials such as animal manure, crop residues, and food scraps. These waste materials, which are high in biodegradable organic matter, are effectively transformed into biogas, a flexible energy source that can be utilized to produce electricity [8-15].

3. METHODOLOGY

Thermal waste-to-energy, or the process of generating electricity by burning waste materials, usually uses the following techniques:

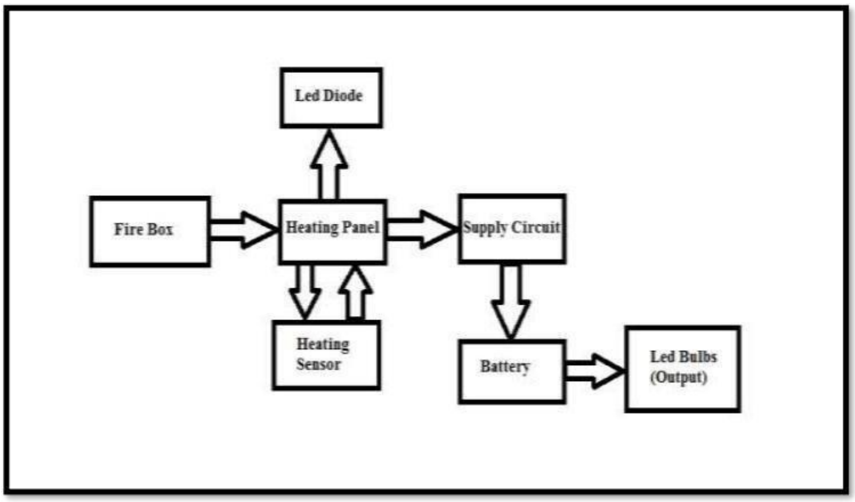
1. Waste collection and transportation: A waste-to-energy plant accepts waste materials that are assembled from a difference of scenes, including homes, companies, and industries.

2. Waste handling and preparation: Non-combustible materials like metals, stones, and glass are indifferent from waste materials by unloading and handling them. After that, the waste is ragged to make it smaller and easier to burn.
3. Incineration: The organized waste is burned at high temperatures, typically between 850°C and 1200°C, in a combustion chamber to generate gases and heat.
4. Energy recovery: The waste material is burned in the box while the heat produced by the incineration process is converted into electricity using heating panels and red LED bulbs that glow when powered by electricity. The circuit then produces electricity and gives it to the battery to charge it.

   Before discharging into the atmosphere, the exhaust gases molded during combustion are treated to reduce dangerous pollutants.

   Ash management: The excess ash from the burning process is collected and taken to a landfill to be disposed of.

4. BLOCK DIAGRAM



5. MAIN COMPONENTS

a) Heating Panels

Depending on the particular technology employed, heating panels can be utilized in a number of ways to generate electricity from waste (Figure 1).

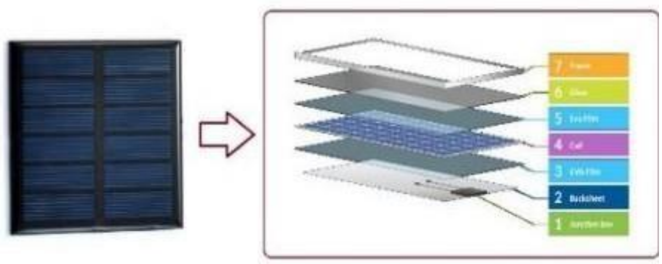


Fig. 1- Heating Panels

b) Heating Sensor

Many waste-to-energy technologies that use thermal processes, like gasification and incineration, rely heavily on heating sensors (Figure 2). These sensors are used to measure temperature at different stages of the process, giving useful data that can be utilized to maximize system efficiency and guard against damage [16-20].

Fig. 2- Heating Sensor

c) Battery

There are several applications for batteries in the process of producing electricity from waste. Electrical energy can be chemically stored in batteries and released when needed to power other electrical devices.

Batteries are frequently used in waste-to-energy plants to store extra energy produced during times of low demand or low generation. A more steady and dependable source of electricity can be produced by storing this extra energy in batteries and using it to augment the plant's output during times of high demand or low generation (Figure 3).

Fig. 3 Battery

d) Led Bulbs

There are some ways to produce electricity from waste materials using LED bulbs. Light-emitting diodes (LEDs) are used in LED bulbs, a type of lighting skill that is prominent for its robustness, long lifespan, and energy proficiency.

LED bulbs can be used in waste-to-energy plants to light different places, such as maintenance facilities, storage parts and control rooms (Figure 4). Over time, LED bulbs can help lower energy consumption and maintenance charges because they use less energy than conventional glowing bulbs and have a longer span [21].

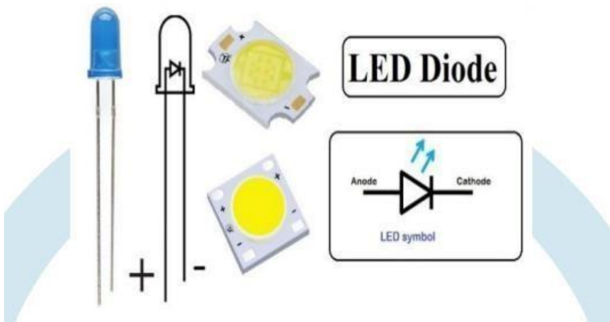


Fig. 4- Led Bulb

6. WORKING

For this plan, we first collect waste or unwanted materials like wood, paper, rubber, and plastic. Heat energy is then formed when those unsafe materials are burned in the Zar box. The solar panel, a device that turns entirely on heat or light energy and transforms thermal energy into electrical energy, receives the heat. The electricity generated by the unused materials is then converted into a charging circuit, which allows us to charge the 12-volt rechargeable battery.
The battery stores the produced electricity. LEDs are turned on by a rechargeable battery, and the water purifier uses the carbon dioxide produced during the burning of waste materials to filter out unsafe gases (Figure 5).

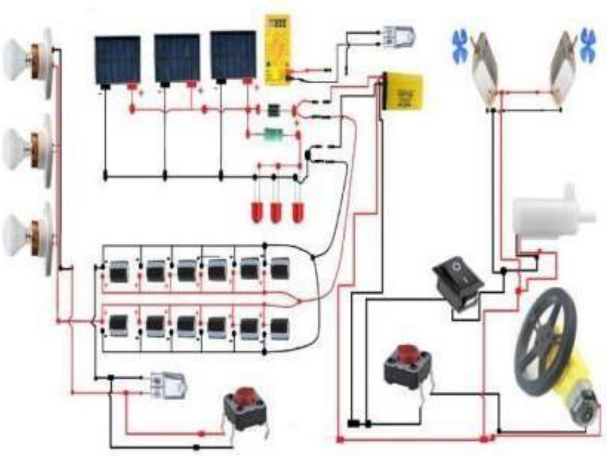


Figure. 5: Circuit Diagram

7. Mathematicals Expression :

Electricity generation from waste material can be understood with numeric examples.

Incineration Example

Suppose a waste-to-energy plant burns 1 ton (1000 kg) of municipal solid waste (MSW). On average, this can generate about 550 kilowatt-hours (kWh) of electricity per ton of MSW [22].

For example:

Waste processed: 1 ton = 1000 kg

Electricity generated: 550 kWh

So, if a city produces 100 tons of waste per day:

Total electricity generated per day = 100 × 550 = 55,000 kWh

Biogas Example

By using the biomethanation process, 20–25 kg of cattle dung can generate 1 cubic meter (m^3) of biogas. Each 1 m^3 of biogas has the potential to generate 2 units (kWh) of electricity.

Example calculation:

Cattle dung used: 25 kg → biogas produced: 1 m^3 → electricity: 2 kWh

If 250 kg of dung is used:

Total biogas: 250 kg ÷ 25 kg per m^3 = 10 m^3

Electricity: 10 m^3 × 2 kWh = 20 kWh

General Formula Application

If the efficiency (η\etaη) of the waste-to-energy plant is 20% and the waste contains 7500 MJ/ton enegy:

$$E=\eta\times Q$$
$$E=0.2\times 7500=1500 \text{ MJ}$$

Converting MJ to kWh:

$$1 \text{ kWh}=3.6 \text{ MJ}$$
$$1500/3.6=416.7 \text{ kWh}$$

This means 1 ton of waste can yield about 416.7 kWh of electricity at 20% plant efficiency.

8. RESULT

Heating panels in this prototype will gather the heat produced when we begin heating waste materials inside the Zaar box. The heating panels will capture heat energy and convert it into electrical energy, which will subsequently be transmitted to the circuit board.. which is built using an IN4007 diode and capacitor connected in parallel and series to boost the amount of energy produced and force it into the battery. After that, the heating sensor will detect heat and connect the circuit to the LED bulbs' output. The bulbs will continue to glow until the energy is stored and the heating sensor detects the generation of energy. While the battery is being stored and energy is being generated, the bulb will continue to glow. Anything can be done with this stored energy.In the current scenario, waste material can be found everywhere. With a certain process, we can gather everything and use the prototype to produce more energy for use.

This led us to conclude that, with careful handling, generating energy using this approach is fairly straightforward. The prototype provides insights into effective waste utilization. Through this project, we can generate additional energy for industrial applications and employ it for multiple purposes.

9. CONCLUSION

The system has been designed with features that seamlessly connect all hardware components. Each module has been carefully selected and strategically placed to optimize the unit's performance. Additionally, the project was executed successfully using highly advanced integrated circuits (ICs) supported by modern technological developments, leading to successful design and testing outcomes.

10. REFERENCES

1. Ríos, M., &Kaltschmitt, M. (2016). Electricity generation potential from biogas produced from organic waste. *Renewable and Sustainable Energy Reviews*, 54, 384–395.
2. Rajaeifar, M. A., Ghanavati, H., Dashti, B. B., Heijungs, R., Aghbashlo, M., & Tabatabaei, M. (2017). Electricity generation and GHG emission reduction potentials through municipal solid waste management technologies. *Renewable and Sustainable Energy Reviews*, 72, 535–553.
3. Jha, S., *et al*. (2022). Thermochemical conversion of waste: pyrolysis, gasification, and energy recovery. *Energies*, 15(17), 6352.
4. Alao, M. A., *et al*. (2022). Waste-to-energy nexus: An overview of technologies and global challenges. *Renewable and Sustainable Energy Reviews*, 163, 112471.
5. Traven, L., *et al*. (2023). Sustainable energy generation from municipal solid waste: Current technologies and future prospects. *Sustainability*, 15(4), 3568.
6. Wang, Y., *et al.* (2023). Thermochemical conversion of biomass and waste: Future pathways for bioenergy. *Renewable Energy*, 205, 672–690.
7. Quan, C., *et al*. (2025). Thermochemical waste conversion technologies: A comprehensive review. *Renewable Energy Reviews*, 18, 112–128.
8. International Energy Agency (IEA). (2021). Will energy from waste become the key form of bioenergy in Asia? *IEA Bioenergy Report.*
9. World Bank. (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. *World Bank Publications.*
10. IEA Bioenergy. (2018). Annual Report 2018: Bioenergy and Waste-to-Energy Systems. *IEA Bioenergy.*
11. Sharma, A., & Jain, S. (2019). Power generation using municipal solid waste: A review of technology options. *Energy Conversion and Management*, 196, 616–630.
12. Kumar, S., et al. (2017). Municipal solid waste management and waste-to-energy: Challenges and global status. *Renewable and Sustainable Energy Reviews*, 80, 459–478.
13. Brunner, P.H., & Morf, L.S. (2024). Waste to energy, indispensable cornerstone for circular economy: A mini-review. Waste Management Research, 43(1), 26–38.
14. Soni, A., *et al.* (2025). Waste-to-energy technologies: a sustainable pathway for a decarbonized future. Materials Advances, 6(23), 4712–4724.
15. Subiza-Pérez, M., *et al*. (2023). Waste-to-energy risk perception typology: health, politics, and climate consequences. Journal of Risk Research, 26(10), 1527-1542.
16. Goud, R., Verma, I., Singh, P.K., & Shailendu, T. (2025). Sustainable energy from waste: A review of modern power generation techniques. IJERT, 13(06).
17. Babel, S., & Kumar, A. (2020). Review of Technologies for Converting Organic Waste to Electricity. Renewable and Sustainable Energy Reviews, 130, 109955.
18. Papong, S., Kiatsiriroat, T., & Dechapanya, S. (2018). A Review of Municipal Solid Waste-to-Energy Technologies. Energy Procedia, 153, 21–26.
19. Lam, S.S., Tan, K.T., Lee, K.T., & Mohamed, A.R. (2019). E-Waste: An Overview of the World's Most Rapidly Growing Waste Problem. Critical Reviews in Environmental Science and Technology, 49(6), 380-403.
20. Shukla, M.K. (2020). Waste to Energy: A Review on Generating Electricity in India. SAMRIDDHI – A Journal of Physical Sciences, Engineering and Technology, 12(1), 37–40.
21. Singh, R., & Verma, V. (2022). Generate Electricity by Waste Material Project. The RS Industries, VMK Technical Power, Uttar Pradesh, India.
22. Kalyani, K.A., & Pandey, K.K. (2014). Waste to energy status in India: A short review. Reneable and Sustainable Energy Reviews, 31, 113–120.