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RESEARCH ARTICLE OPEN ACCESS

Waste-To-Electricity Generation for Sustainable Power by Using Plastic Waste

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Abstract:

The increasing generation of plastic waste has become one of the most critical environmental challenges due to its non-biodegradable nature and improper disposal methods. Waste-to-electricity generation through incineration offers a sustainable and efficient solution for managing this growing problem while recovering valuable energy. In this process, plastic waste is subjected to controlled combustion at high temperatures, converting the waste into thermal energy. The generated heat is then used to produce steam, which drives turbines to generate electricity. This method not only reduces the volume of plastic waste significantly—by up to 90%—but also minimizes landfill dependence and contributes to energy recovery. Furthermore, modern incineration plants are equipped with advanced flue gas cleaning systems that control harmful emissions such as dioxins, furans, and particulate matter, making the process environmentally viable. The study emphasizes the operational principles, energy conversion efficiency, and emission control technologies involved in the incineration process. It also highlights the potential of integrating this technology within a circular economy framework to promote sustainable waste management and renewable energy generation. Overall, the incineration of plastic waste provides a dual benefit: mitigating environmental pollution and generating clean, usable electricity, thus representing a promising approach toward achieving energy sustainability and waste minimization goals.

Keywords: Plastic waste, Incineration process, Waste-to-energy, Electricity generation, Thermal conversion, Sustainable waste management

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Introduction:

Sustainable Solution: Waste-to-electricity (WtE) generation offers a sustainable approach to waste management and energy production.

Waste Reduction: WtE technologies can significantly reduce the volume of waste sent to landfills.

Renewable Energy Source: Waste can be a reliable and consistent source of renewable energy.

Greenhouse Gas Reduction: WtE generation can help mitigate climate change by reducing greenhouse gas emissions.

Clean Energy: WtE can generate clean energy, reducing dependence on fossil fuels.

Waste Management: WtE promotes sustainable waste management practices, encouraging waste reduction and recycling.

Technologies: Various technologies, including incineration, pyrolysis, and anaerobic digestion, can be used for WtE generation.

Circular Economy: WtE generation can help create a more circular economy, reducing waste and promoting sustainable development.

1.1 DEFINITION:

Waste-to-electricity (WtE) generation is the process of converting waste materials into electricity or heat. This approach offers a sustainable solution for waste management while producing renewable energy.

1.1.7 ADVANTAGES

Energy Recovery: Plastics have a high calorific value, producing significant heat and electricity.

Waste Volume Reduction: Reduces plastic waste volume by up to 90%, decreasing landfill use.

Continuous Power Supply: Provides stable, base-load electricity unlike solar or wind.

Reduction of Land Pollution: Prevents plastic accumulation in landfills and the environment.

Supports Waste Management: Useful for non-recyclable plastics that cannot be reused.

Heat Utilization: Excess heat can be used for district heating or industrial processes.

1.11 PROBLEM DEFINITION:

Plastic Waste to Electricity Generation Using Incineration Process, the rapid increase in plastic consumption has led to a serious plastic waste management problem, causing environmental pollution, landfill overflow, and health hazards. Plastics are non-biodegradable and persist in the environment for hundreds of years, making their disposal a major challenge for urban and industrial areas. At the same time, the growing demand for electricity and the depletion of fossil fuel resources have created an urgent need for alternative energy sources.

1.12 LANDFILLING AND OPEN DUMPING OF PLASTIC WASTE RESULT IN:

Long-term environmental pollution
Soil and groundwater contamination
Loss of potential energy contained in plastics

Therefore, there is a need for an effective solution that can safely dispose of plastic waste while recovering useful energy. The problem addressed in this study is to convert plastic waste into electricity using the incineration process, where plastic waste is combusted under controlled conditions to generate heat, which is then used to produce steam and drive turbines for electricity generation. The key challenge is to maximize energy recovery while minimizing environmental emissions, health risks, and operational costs.

LITERATURE REVIEW:

K. B. Bodke et, al., [1] "Generation of Electricity from Waste Material," This study presents a thermal waste-to-energy system that converts municipal and industrial waste into electricity using controlled combustion. Waste materials are burned in a combustion chamber, producing heat that is captured using heating panels and converted into electrical energy. The generated power is regulated through booster circuits and stored in batteries for later use. The system demonstrates effective waste volume reduction, renewable electricity generation, and reduced methane emissions compared to landfilling. Pollution control is achieved through water-based filtration of exhaust gases. Experimental results show successful illumination of LED loads, validating the feasibility of the system at a small scale. The study highlights environmental and economic benefits, particularly for decentralized energy generation. However, efficiency improvement and scalability remain challenges. Overall, the work supports waste-to-energy as a sustainable solution for waste management and local electricity production.

N. Adhikari et, al., [2] "Generation of Electricity from Municipal Solid Waste," This paper investigates electricity generation from municipal solid waste (MSW) with emphasis on waste paper and cloth. The system involves manual waste segregation, combustion in a heating box, and heat-to-electricity conversion using heating panels. Approximately 200 g of waste produced 0.17 kWh of electricity, which was stored in a 6 V battery. Circuit components such as capacitors, resistors, and diodes stabilized and protected the electrical output. Pollution was controlled using a water filtration unit to reduce harmful emissions. The study demonstrates a simple and practical approach to waste-to-energy conversion for small-scale applications. However, the low capacity of heating panels resulted in longer generation time, indicating a need for improved heat recovery efficiency. The work concludes that MSW-based electricity generation is feasible and environmentally beneficial when combined with proper segregation and emission control.

N. Kumbar et, al., [3] "Electricity Generation from Municipal Solid Waste," This research explores electricity generation from municipal solid waste using incineration and thermoelectric conversion. Waste is collected, segregated, and burned in a heating box, producing thermal energy that is converted into electricity using heating panels and thermoelectric generators. The generated power is stored in batteries and used to operate LED loads. The system integrates pollution control through water filtration and ash management, ensuring environmental compliance. Experimental results showed that burning approximately 15 g of waste produced 25–30 W of power, demonstrating suitability for small-scale and remote applications. The study highlights the role of waste-to-energy systems in reducing landfill dependency, greenhouse gas emissions, and power shortages. However, it emphasizes the need for better heat capture, storage efficiency, and scalability for wider implementation. The work supports MSW-based energy recovery as a sustainable renewable energy option.

M. Deosarkar et, al., [4] "Electricity Generation Using Waste Material," This paper examines electricity generation from waste materials such as plastics, rubber, and municipal solid waste using incineration and gasification techniques. Heat produced during combustion is converted into electricity using heating panels and boosted using electric coils to improve output. The system incorporates batteries for energy storage and air filtration units for emission control. The study discusses technical feasibility, environmental benefits, and economic considerations of waste-to-energy systems. Results indicate effective reduction of landfill waste and recovery of usable energy, though CO_2 emissions remain a concern. Advanced pollution control systems help reduce particulate matter and toxic gases. The research concludes that waste-to-energy can be a reliable renewable energy source if technological optimization, policy support, and public acceptance challenges are addressed. The study contributes to understanding integrated waste management and sustainable power generation.

V. Chaudhari et, al., [5] "Electricity Generation from Solid Waste," This study proposes a method to generate electricity from municipal, industrial, and agricultural solid waste using incineration and heat recovery. Waste is burned in a controlled fire box, and the generated heat is converted into electrical energy using heating panels. The power is stored in batteries through booster circuits, with diodes preventing reverse current. Carbon capture plates and exhaust filters are used to reduce greenhouse gas emissions. Experimental results confirm the system's ability to power electrical loads while significantly reducing waste volume. The research emphasizes sustainability, reduced landfill dependency, and renewable energy generation. However, challenges related to energy conversion efficiency, equipment cost, and long-term durability are identified. The study concludes that solid waste-based electricity generation is a viable decentralized energy solution with scope for further optimization.

H. Sharma et, al., [6] "Electricity Generation from Waste Materials," This paper focuses on electricity generation from waste materials using controlled incineration and heating panel technology. Waste is burned at high temperatures to produce heat, which is converted into electrical energy and stored in batteries. The system includes booster circuits, diodes, capacitors, and heat sensors for regulation and safety. A water-based filtration system reduces air pollution by removing particulates from exhaust gases. Experimental observations show stable electricity generation capable of powering LED loads. The study highlights reduced landfill use, prevention of methane emissions, and decentralized power generation benefits. Limitations include low power output and dependence on heating panel efficiency. The authors conclude that waste-to-energy systems are suitable for small-scale applications and can be expanded with improved panel design and storage capacity.

S. Sharma and V. Mishra, "Generation of Electricity from Solid Waste without Air Pollution," This study presents an environmentally conscious waste-to-energy system designed to minimize air pollution. Municipal and industrial waste is combusted in a controlled fire box, and the generated heat is converted into electricity using heating panels. The electrical output is stored in batteries and used to power loads such as LEDs. Pollution control measures, including filters and carbon collection plates, significantly reduce harmful emissions. The system demonstrates effective waste reduction and energy recovery with minimal environmental impact. Analysis of existing waste-to-energy plants in India supports the scalability of the approach. The study concludes that with proper emission control and system optimization, waste-to-energy technologies can provide sustainable electricity for residential, industrial, and agricultural applications.

N. S. Munde et, al., [8] "Generate Electricity by Using Waste Material," This paper investigates electricity generation from waste materials such as plastics, rubber, and household garbage. The system uses controlled burning to produce heat, which is converted into electrical energy using heating panels and thermoelectric principles. The electricity is stored in rechargeable batteries and demonstrated through LED illumination. Pollution control filters reduce harmful gas emissions by nearly 50%. Experimental results confirm technical feasibility and environmental sustainability. The study highlights land conservation benefits by reducing landfill dependency and compares favourably with conventional thermal power plants in terms of pollution levels. Although initial costs are high, long-term benefits make the system economically viable. The research concludes that waste-to-energy systems can address both waste management and renewable energy needs effectively.

K. Vijay Kumar et, al., [9] "Generation of Electrical Energy by Reutilizing Low-Grade Waste," This study explores electricity generation from low-grade domestic and industrial waste using thermoelectric heating panels based on the See beck effect. Combustion heat is converted into low-voltage electricity, which is boosted using a DC–DC converter and stored in batteries. The system successfully powered LEDs and demonstrated stable energy output. Pollution control was achieved using carbon filters, though some components such as cooling pumps required external power. The research highlights the system's low cost, modular design, and suitability for decentralized energy applications. However, complete self-sustainability remains a challenge. The authors conclude that thermoelectric waste-to-energy systems are promising for small-scale renewable energy generation with further optimization.

S. Reddy et, al., [10] "Generation of Electricity by Trash, Plastic & Non-Biodegradable Waste," This paper presents a waste-to-energy model that converts plastic, rubber, paper, and wood waste into electricity through incineration. Heat generated during combustion is converted into electrical energy using heating panels and stored in rechargeable batteries. Pollution control systems, including filters and water purifiers, reduce harmful emissions. Experimental results show successful power generation demonstrated by LED lighting. The system reduces landfill use, supports renewable energy generation, and offers a cost-effective solution for local electricity needs. The study concludes that integrating waste management with energy recovery can provide sustainable and environmentally friendly power, particularly for small-scale and community-level applications.

METHODOLOGY:

3.1 OBJECTIVES OF THE STUDY:

The main aim of the investigational work is to plastic waste to electricity generation by using incineration process to reduce plastic waste accumulation by safely disposing of non-recyclable plastic materials to generate electricity by utilizing the high calorific value of plastic waste through controlled incineration. To minimize landfill dependency and extend the lifespan of existing landfill sites. To recover useful energy from plastic waste in the form of heat and electrical power. To reduce environmental pollution caused by open dumping and uncontrolled burning of plastics. To implement a sustainable waste management solution that integrates waste treatment with energy production. To ensure controlled combustion with proper emission control systems to limit harmful gases and particulates. To support alternative energy production and reduce dependence on fossil fuels. To improve urban sanitation and public health by effective plastic waste disposal. To promote circular economy principles by converting waste into a valuable energy resource.

3.2 SELECTION OF PLASTIC WASTE:

The selection of plastic for electricity generation is driven by several key factors:
Plastics are hydrogen and carbon-rich materials derived from crude oil, giving them a latent energy content that rivals or exceeds traditional fossil fuels.
Superior to Coal: Many plastics have a heating value of 38–46 MJ/kg, which is significantly higher than that of bituminous coal (~28 MJ/kg), wood (~16 MJ/kg), or paper (~15 MJ/kg).
Fossil Fuel Substitute: One kilogram of plastic packaging can contain between 25,000 and 46,000 kilojoules of energy, making it an efficient substitute for coal or oil in power plants.
Plastics can be converted into electricity through several advanced thermal processes:
Incineration (Energy-from-Waste): Direct combustion of plastics generates heat to boil water and drive steam turbines for electricity.
Plastic bottles are versatile containers made from various types of plastic, used for storing a wide range of liquids from water and oil to medicines and chemicals. They are popular for their lightweight and durable nature. Reusable Plastic Bottles, these bottles are designed for repeated use, helping to save money and reduce plastic waste. They are typically made from high-quality, food-grade, BPA-free plastics to ensure safety. Plastic is selected for "plastic-to-electricity" conversion primarily because of its exceptionally high energy content, which stems from its petroleum-based origins. This process, often referred to as energy recovery or quaternary recycling, treats non-recyclable plastic as a valuable fuel source rather than just waste.

3.3 DEFINATION OF PLASTIC:

Plastic is a synthetic material made from polymers—large molecules composed of repeated subunits. These polymers are derived from petrochemicals, primarily crude oil and natural gas, through a process called polymerization. The resulting material can be moulded into various shapes when heated and exhibits a wide range of physical properties depending on the specific polymers used and the manufacturing process.

PROCESS OF WASTE PLASTIC BY USING INCINERATION:

Definition: Thermal treatment of waste in the presence of oxygen to convert it into:
Ash (solid residue)
Flue gases (smoke containing CO_2, water vapor, and pollutants)
Heat (can be used to produce electricity or steam)
Purpose:
Reduce waste volume by 70–90%
Reduce hazardous components
Generate energy in waste-to-energy (WTE) plants

STEP BY STEP PROCESS OF THE INCINERATION:

Step 1: Waste Collection and Sorting
Waste is collected and sorted.
Non-burnable materials (metal, glass) are removed.
Step 2: Feeding the Incinerator
Waste is fed into the combustion chamber.
For plastic waste, high calorific value makes it good for energy production.
Step 3: Combustion
Waste is burned at 800–1200°C.
Oxygen ensures complete combustion.
Plastic releases energy and produces CO_2, water vapor, and some toxic gases.
Step 4: Energy Recovery (Optional)
Heat generated is used to:
Heating panel → thermal energy to electricity generation.
Step 5: Flue Gas Treatment
Flue gases are treated to remove harmful pollutants:
Particulates → via filters or electrostatic precipitators
Acidic gases → via scrubbers
Dioxins and heavy metals → via catalytic converters or activated carbon
Step 6: Ash Handling
Bottom ash (non-combustible residue) can be:
Used in construction (after treatment)
Landfilled safely
Plastic Waste to Energy (WtE): Using plastic waste as a fuel to generate electricity or heat. Benefit: Converts non-recyclable plastic into energy. Reduces dependence on fossil fuels
Hazardous Waste Disposal: Incineration of chemical, medical, or industrial waste. Safely destroys toxic substances. Prevents environmental contamination.
Industrial Waste Management: Burning by-products or residues from factories. Benefit: Reduces storage needs for industrial waste. Generates heat or energy for industrial processes
Energy Recovery in Remote Areas: Small-scale incinerators in remote communities to generate electricity. Benefit: Provides electricity where grid access is limited. Reduces environmental pollution from open burning of waste. Biomedical and
Infectious Waste Treatment: Incinerating hospital and lab waste. Benefit: Eliminates pathogens. Prevents contamination of water and soil.

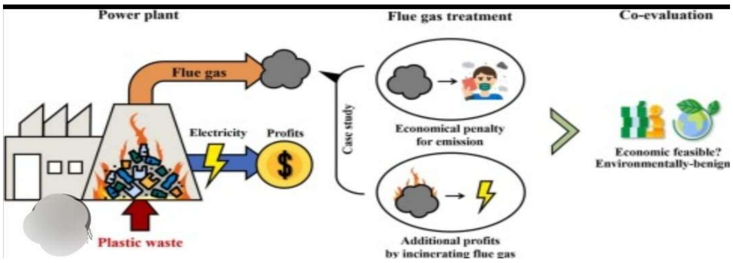


Fig: 3.3- Incineration process

WORKING PROCESS:

Preparation of the Base: Start by securing a flat wooden or cardboard base.

Setting up the Heat Source: In the centre, place a small furnace or heating chamber. This is burned to create the initial thermal energy.

Cooling System Integration: On the right side, set up a water tank and a cooling circuit. Use a small pump and plastic tubing to circulate water. This creates the necessary temperature difference between the hot and cold sides.

Energy Conversion: Place the TEG modules between the heat source and the cooling pipes. As heat moves toward the cold water, the modules generate a DC voltage.

Circuit Connection: Connect the output wires to a electrical circuit and capacitors on the left. This stabilizes the power to light up the LED bulbs.

Testing: Ignite the heat source and start the water circulation. Once the temperature gap is wide enough, the bulbs will glow.

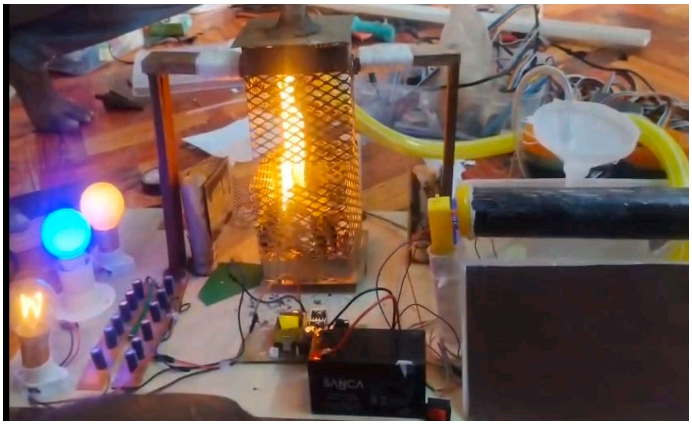


Fig. 3.4- burning of plastic bags

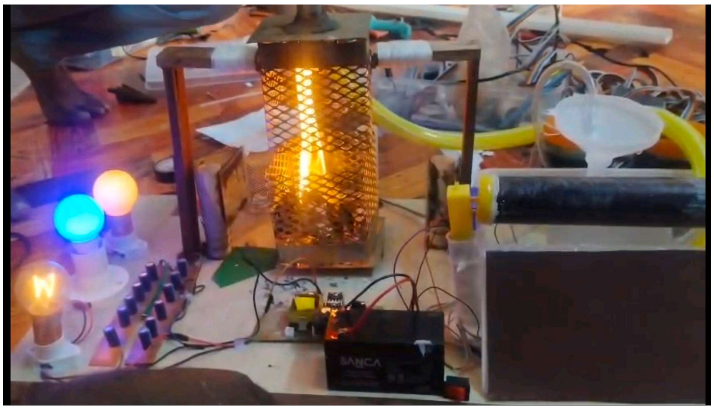


Fig. 3.5- burning of plastic bottles

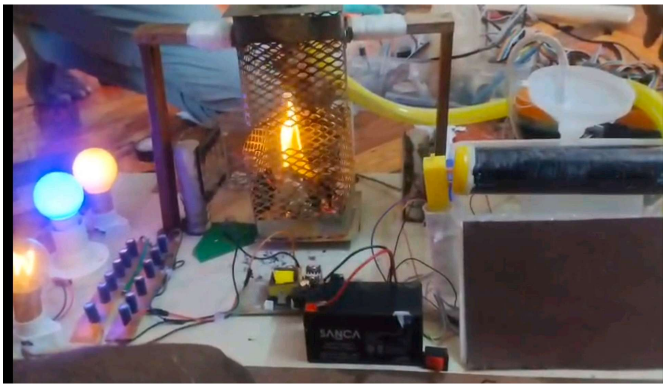


Fig. 3.6 burning of papers

CALCULATION:

To estimation calculate the electricity generated from plastic waste through incineration, To operate your 4V bulbs using the incineration of 1 kg of waste, the system must maintain a specific thermal-to-electrical conversion rate. By integrating a heating sensor, you can monitor the combustion temperature to ensure maximum efficiency. As shown in table: 1

S.no	Materials	Thermal energy (MJ)	Electrical energy (Wh)	Current (Ah)
1	Plastic bottle	23	128	32.0

	(PET)			
2	Paper	15	83	20.8
3	Plastic bags(PE)	46	256	64.0
4	Average	28	156	39.0

Materials table: 1

1. Calculations for 1 kg Mixed Waste (Incineration)

We assume 1 kg of a mixed sample (Plastic Bottles, Paper, and Plastic Bags).
Total Thermal Energy Potential: ~28 MJ (approximately 7.78 kWh).
System Efficiency: we estimate a 2% conversion efficiency.
Total Electrical Energy:
=7.78kWh × 0.02
= 0.1556kWh (or 155.6Wh}).
Output Parameters:
If the waste is incinerated over a 5-hour period:
Voltage (V): 4.0V (Regulated for your bulbs).

Power (P): 155.6Wh ÷ 5 hours
= 31.1 Watts.

Current (I) = P ÷ V
= 31.1W ÷ 4V
= 7.78 Amperes.

Heating Sensor Monitoring:
The heating sensor is crucial for the incineration process. Most plastics incinerate efficiently between 400 Cand 600 C.
Sensor Location: Placed near the combustion core.
Expected Reading: Approxi 425 C.
Purpose: If the temperature drops below 300 C, the plastic won't burn completely (creating more smoke).
Net Electrical Energy:
= 7.78 kWh × 0.02
= 0.156 kW (or 156 Wh).
Multimeter:
Shows the output of 4 V and 7.78 A.
Heating Sensor:
Shows a stable core temperature of 425.0 C.
Bulb Performance (4V System)
With a continuous output of 7.78 Amp:
Single 4V Bulb: If your bulb is a 1W LED (0.25 A), the current produced can power 31 bulbs at the same time.
Capacity: The energy from 1 kg of waste is enough to run one 4V bulb for over 150 min if stored in a battery, or 31 bulbs for the duration of the 20-min burn.
MULTIMETER READING:

S.no	Tools	Reading	Context
1	Multimeter (V)	4.0 V	Regulated to match our bulbs rating
2	Multimeter (A)	7.8 A	Based on a 20 min steady burn of 1 kg

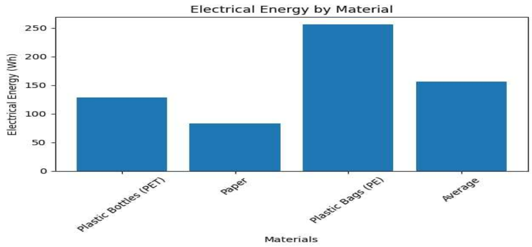
Multimeter reading table: 2

How long will the bulbs glow:
The "glow time" depends on the wattage (power) of the 4V bulbs you are using.
Let's assume you are using 4 -Watt LED bulbs (which draw 0.25 A at 4 V).
Total Energy Available: 156 Watt-hours (as shown in table: 3)

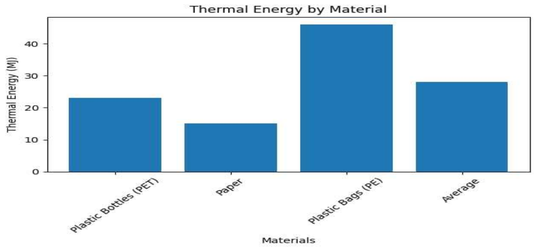
S.no	Number of bulbs	Total power	Glow time
1	1 bulbs	6 w	10 min
2	3 bulbs	18 w	6 min

Bulbs glow table: 3

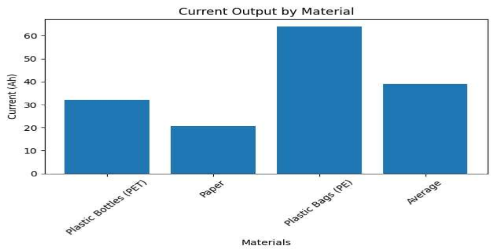
RESULT AND DISCUSSION:



Electrical energy graph- 1

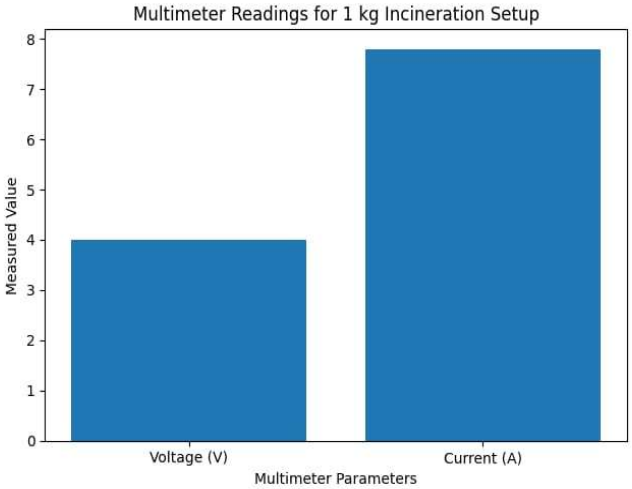


Thermal energy graph- 2



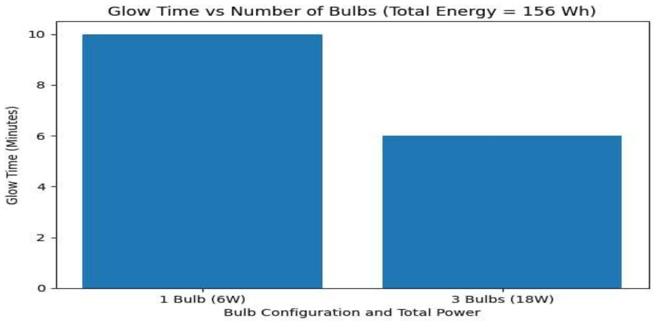
Current output graph-3

The graphs- 1, 2, 3, show a comparison of materials based on thermal energy (MJ), electrical energy (Wh), and current output (Ah) for 1 kg of waste. Plastic Bags (PE) produce the highest thermal energy (46 MJ), resulting in the highest electrical energy (256 Wh) and current (64 Ah). Plastic Bottles (PET) generate 23 MJ thermal energy, converted to 128 Wh electrical energy and 32 Ah current. Paper produces the lowest values: 15 MJ thermal energy, 83 Wh electrical energy, and 20.8 Ah current. The average mixed waste gives 28 MJ thermal energy, 156 Wh electrical energy, and 39 Ah current, showing moderate performance among all materials.



Multimeter reading graph- 4

As shows the graph-4 the multimeter readings obtained from the incineration of 1 kg of mixed waste. The measured voltage is 4.0 V, which is regulated to match the rating of the 4V bulbs used in the setup. The current reading is 7.8 A, recorded during a steady 20-minute burn process. These values indicate stable electrical output generated from thermal energy conversion. The constant 4V supply ensures proper bulb operation, while the 7.8A current reflects the power produced during combustion. Together, the readings demonstrate that controlled incineration can generate usable and regulated electrical energy for low-voltage applications.



Total energy graph- 5

The graph-5 shows the relationship between the number of bulbs, total power consumption, and glow time based on 156 Wh of available energy. When using 1 bulb with 6W total power, the glow time is 10 minutes. When using 3 bulbs with 18W total power, the glow time reduces to 6 minutes. This clearly shows that as total power consumption increases, the glow time decreases. Higher wattage consumes stored electrical energy faster. Therefore, energy duration is inversely proportional to load power. Efficient load management is important to maximize lighting duration in waste-to-energy systems using incineration-generated electricity.

BASED ON THE TOTAL GRAPHS DATA:
Based on the generated graphs, the experimental results clearly show the relationship between waste type, electrical output, and bulb performance.

From the materials comparison graph,
Plastic Bags (PE) produced the highest thermal energy (46 MJ), electrical energy (256 Wh), and current (64 Ah).
Plastic Bottles (PET) generated moderate values (23 MJ, 128 Wh, 32 Ah), while
Paper produced the lowest output (15 MJ, 83 Wh, 20.8 Ah).
The average mixed waste yielded 28 MJ thermal energy and 156 Wh electrical energy, indicating balanced performance.

The multimeter graph confirms a regulated voltage of 4.0 V and a steady current of 7.8 A during a 20-minute burn, showing stable power generation.

The bulb performance graph shows that glow time decreases as power consumption increases. One 6W bulb glows for 10 minutes, while three 18W bulbs glow for 6 minutes. This proves that higher load reduces operating duration.

Overall, the results demonstrate that plastic waste, especially PE, provides higher energy output, and efficient load management is essential for maximizing usable electrical energy.

BASED ON THE THERMAL ENERGY, ELECTRICAL ENERGY, AND CURRENT OUTPUT GRAPHS, A CLEAR PERFORMANCE DIFFERENCE IS OBSERVED AMONG:

PLASTIC BAGS (PE) show the highest energy potential. They produce 46 MJ thermal energy, which converts to 256 Wh electrical energy and 64 Ah current. This indicates that PE has a higher calorific value and better energy recovery during incineration.

PLASTIC BOTTLES (PET) show moderate performance, generating 23 MJ thermal energy, 128 Wh electrical energy, and 32 Ah current. PET produces nearly half the energy of PE, making it a secondary option for energy generation.

PAPER produces the lowest output with 15 MJ thermal energy, 83 Wh electrical energy, and 20.8 Ah current. This is due to its lower calorific value compared to plastics.

OVERALL CONCLUSION:

The experimental study demonstrates that incineration of 1 kg of mixed waste can effectively generate electrical energy sufficient to power low-voltage bulbs. Among the materials tested, Plastic Bags (PE) exhibited the highest energy potential, producing 46 MJ of thermal energy, 256 Wh of electrical energy, and 64 Ah of current. Plastic Bottles (PET) showed moderate energy output, while Paper contributed the least, highlighting the importance of material selection for energy recovery. Multimeter readings confirmed a stable voltage of 4.0 V and a current of 7.8 A during a controlled 20-minute burn, ensuring regulated power for connected devices. Bulb performance analysis revealed an inverse relationship between total power consumption and glow time: one 6W bulb glowed for 10 minutes, while three 18W bulbs glowed for 6 minutes. Overall, the study confirms that controlled incineration of plastic-rich waste provides a reliable source of electrical energy, and careful load management optimizes energy utilization, making waste-to-energy conversion a feasible solution for small-scale power applications.

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