International Journal on Theoretical and Applied Research in Mechanical Engineering

ISSN: 2319-3182

Volume 12 Issue 1 (2023) | Pages: 1-7

# Generation of Electricity from Municipal Solid Waste: A Design and Experimental Investigation

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**Peer Review Information**

***Type***: *Article*
***Received***: *29 April 2023*
***Revised***: *22 May 2023*
***Accepted***: *18 June 2023*
***Published***: *21 July 2023*

**Abstract**

The disposal of municipal solid waste (MSW) presents a major environmental challenge globally, leading to pollution and resource depletion. This study addresses this issue by designing, constructing, and testing a small-scale waste-to-energy (WtE) model that converts dry municipal solid waste into electrical energy. The system comprises a combustion chamber, an integrated boiler system, a compact steam turbine, and an electric generator. Experimental trials were conducted using different waste categories (wood waste, domestic waste, and mixed waste) to evaluate system performance parameters such as steam pressure, steam flow velocity, turbine speed, and voltage output. The results demonstrate the practical feasibility of harnessing energy from non-recyclable dry waste, offering a sustainable alternative to conventional waste disposal and contributing to renewable energy production.

**Keywords:** Waste-to-Energy; Municipal Solid Waste; Combustion Chamber; Steam Turbine; Renewable Energy.

### How to Cite This Article

Patil, P., Dinde, N., More, P., Patole, V., & Narwade, A. (2023). Generation of electricity from municipal solid waste: A design and experimental investigation. *International Journal on Theoretical and Applied Research in Mechanical Engineering,* 12(1), 1-7.

## Introduction

Managing waste is a critical challenge affecting environments and communities worldwide. Massive daily accumulations of waste lead to pollution, health hazards, and strained resources. Finding sustainable handling solutions is essential for a cleaner, healthier planet. This project addresses the challenge by converting dry waste into electricity. Dry waste—including paper, cardboard, plastics, and textiles—constitutes a substantial portion of the waste stream and possesses valuable untapped energy potential.

The process involves collecting dry waste, feeding it into a combustion chamber for controlled burning to release heat energy, using this heat to produce steam in a boiler, and driving a turbine connected to an electric generator to produce electricity. This offers a sustainable waste management solution, reduces reliance on fossil fuels, and mitigates greenhouse gas emissions.

*Problem Statement*

In contemporary urban environments, municipal solid waste (MSW) management presents a multifaceted challenge involving environmental degradation, public health concerns, and resource depletion. A significant proportion of MSW—particularly dry waste like paper, cardboard, plastics, and textiles—remains non-recyclable and burdensome. This necessitates innovative solutions that alleviate environmental impacts while capitalizing on latent energy potential through scalable WtE systems.

*Objectives*

1. Design and construct a small-scale waste-to-energy plant model capable of generating electricity through municipal dry waste combustion.
2. Gain comprehensive understanding and proficiency in converting heat energy from burning waste into usable electricity.
3. Offer a sustainable, environmentally friendly solution for managing municipal dry waste.
4. Contribute to waste reduction efforts by repurposing dry waste as a resource, thereby reducing landfill volumes.

*Scope*

The project entails designing, constructing, and testing a compact WtE facility. This involves system design, component procurement, assembly, and rigorous functional and efficiency testing. Future scalability and expansion considerations are explored to ensure long-term viability.

*Methodology*

- Research and Analysis: Conduct in-depth research on WtE technology and MSW management practices.
- System Design and Engineering: Develop a robust system design incorporating state-of-the-art equipment to optimize energy generation and minimize environmental impact.
- Procurement and Construction: Procure high-quality materials ensuring adherence to specifications and timelines.
- Testing and Commissioning: Conduct rigorous testing to verify performance and functionality, making necessary adjustments.
- Documentation and Reporting: Maintain detailed documentation of project activities and outcomes.

## Literature Review

Waste-to-energy technologies are a cumulative and integral component of modern scientific waste management processes. King and Stuckenbruck (2019) reviewed energy recovery systems from solid waste, categorizing them into direct utilization of unprepared waste, separated waste utilization, pyrolysis, and biomass conversion. Ryu and Shin (2012) examined combined heat and power (CHP) from MSW in South Korea, noting that power generation efficiency from new plants operating at steam pressures above 20-30 bar is necessary. Zhang et al. (2015) studied WtE challenges and opportunities in China, highlighting high construction costs, corrosion, lower heating values, and public opposition. Lopez (2017) investigated energy recovery from reject materials in Spanish treatment plants. Murphy and McKeogh (2004) examined incineration, gasification, biogas generation, and CHP systems. Appiah (2019) performed a techno-economic assessment in Ghana, finding power generation potentials of 530 kW/tMSW via biochemical conversion and 1320 kW/tMSW via thermochemical conversion. Escamilla-García et al. (2020) evaluated waste combustion in Mexico using LCOE, NPV, and IRR metrics. Chol et al. (2020) explored oxy-fuel combustion integrated with carbon capture (BECCS). Burnley et al. (2011) evaluated energy balances for thermal processing of biodegradable municipal wastes in the UK. Yasmin and Rahman (2017) reviewed solid waste management practices in Dhaka, Bangladesh. Qazi and Abushammala (2020) presented multi-criteria decision analysis methods for selecting optimal WtE technologies. Gu and Liu et al. (2021) analyzed energy recovery potential in Beijing based on multi-scenario MSW separation levels.

## Material Selection and Construction

*Frame*

The frame provides structural support, bears working loads, and mounts all auxiliary components. Selection factors include material availability, suitability for working conditions, cost, physical/chemical properties, and mechanical properties. Machine parts experience forces due to energy transmission, machine weight, frictional resistance, inertia, temperature change, and unbalance. Materials must withstand specific stress types and safety factor constraints based on load predictability and failure modes.

*Material Used: Mild Steel*

Mild steel was selected for construction due to its market availability, economy, standard sizing, good machinability, moderate safety factor, high tensile strength, and low coefficient of thermal expansion.

- Basic Frame: Mild steel angles were cut using a power chop saw, with ends mitered at 900, ground smooth, and welded to form a rectangular base frame.

*MS Sheet Metal*

Mild steel sheets conforming to international standards were utilized. Sheet metal is formed into flat pieces or coiled strips and is classified as plate steel or structural steel when thicknesses exceed 6 mm (0.25 in).

- Fasteners: Hexagonal head bolts and mating nuts were utilized to join components through thread friction, bolt stretch, and part compression.

*Shaft*

A rotating solid cylindrical mild steel shaft (grades 40C8, 45C8, 50C4, or 50C12) transmits power via torque and resists bending moments imposed by mounted pulleys and gears. Shaft materials require high strength, good machinability, low notch sensitivity, heat treatment response, and wear resistance.

*Pedestal Bearings*

Pillow block pedestal bearings (cast iron/steel housing with anti-friction rolling elements) support the rotating shaft parallel to the mounting surface. Standard bearing housing materials include grey cast iron, ductile iron, or stainless steel, with rolling elements made of 52100 chromium steel alloy.

*Nozzle*

A convergent-divergent nozzle controls fluid flow direction and increases velocity by converting pressure energy into kinetic energy.

*Process Sheet*

- Cutting: Performed using a DEWALT power chop saw to create accurate crosscuts at fixed 90° or indexed angles.
- Welding: Performed using a single-phase static electric arc welding transformer suited for melting rutile acid electrodes. Time required: 120 minutes.
- Drilling: Performed on a vertical drilling machine using rotary multi-point drill bits operating at hundreds to thousands of RPM to produce circular cross-section holes.
- Finishing: Performed using a handheld angle grinder with cut-off and grinding discs to eliminate burrs, surface flaws, and achieve proper edge conditioning.

*Safety Precautions*

- Machine parts must be verified for perfect alignment.
- All nuts and bolts must be securely tightened.
- Operating switches must be located at a convenient distance for emergency control.
- Periodic inspection and maintenance must be performed.

**Design**

Consider welding clearance 3.2mm on shaft at circumference $4.42 + (3.2\times2) = 10.82$ mm

But we are using a 12 mm shaft, so our design is safe.

**CAD Drawings**

The complete system assembly and individual components were modeled using SolidWorks 2022.

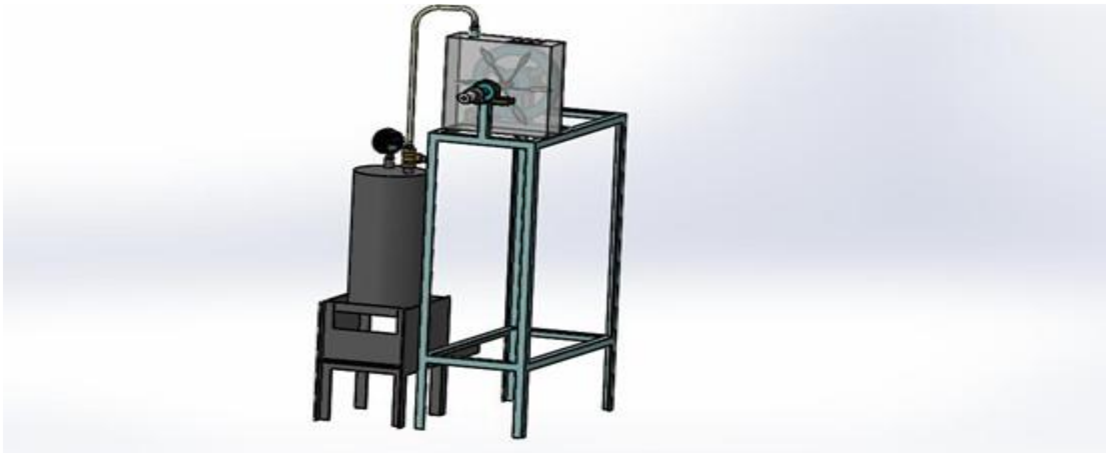

***Fig. 1.*** *Isometric view of the assembled waste-to-energy system model.*

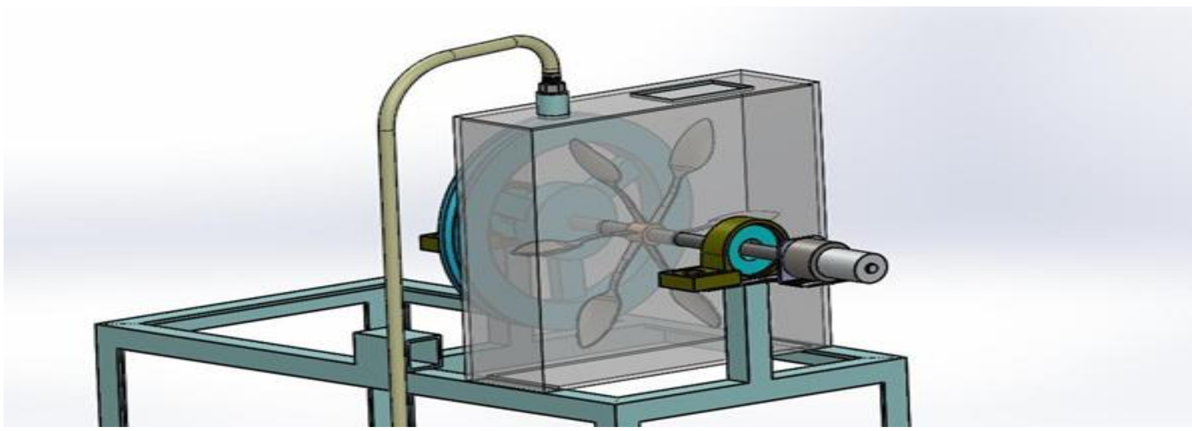

***Fig. 2.*** *Front view of the experimental setup detailing principal assembly dimensions.*

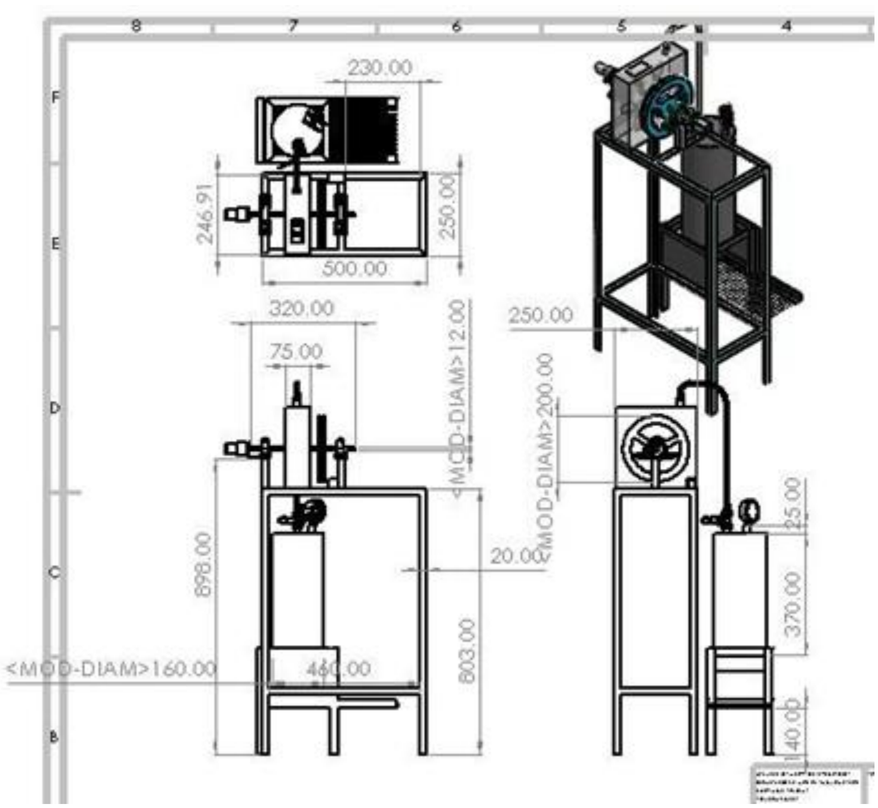


***Fig. 3.*** *Comprehensive 2D engineering drafting with manufacturing dimensions.*

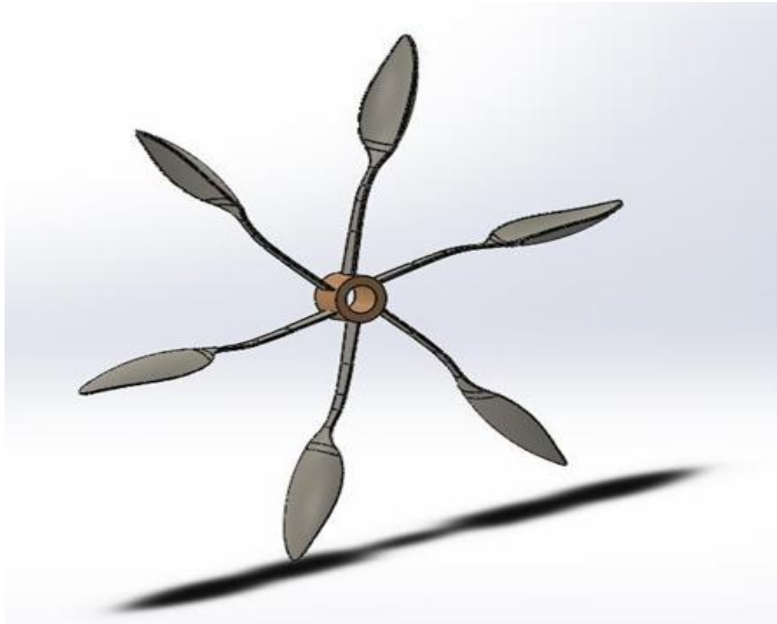

***Fig. 4.*** *Detailed CAD model of the turbine blade.*

**Experimental Validation**

The experimental procedure follows a structured sequence:

1. Waste Collection: MSW is collected from domestic and commercial sources.
2. Sorting and Processing: Recyclables (metals, plastics, glass) are sorted out; organic dry waste (paper, food scraps, yard waste) is retained as feedstock.
3. Combustion: Feedstock undergoes controlled combustion inside the combustion chamber to generate high-pressure steam.
4. Turbine & Generator Operation: High-pressure steam drives the turbine blades, converting thermal-kinetic energy into mechanical rotation and subsequently into electrical energy via the generator.
5. Residue Management & Monitoring: Ash and non-combustible residues are collected for responsible disposal while monitoring systems ensure safety and efficiency.

**Working and Readings**

The system operates by manually sorting non-biodegradable dry waste (paper, cardboard, wood, textiles), shredding to increase surface area, and air-drying to optimize calorific value. The pre-treated waste is burned in the combustion chamber, generating steam that drives a compact turbine connected to a dynamo/generator.

*Experimental Readings Table*

***Table 1.*** *Experimental reading table capturing operational parameters across three distinct waste trials.*

| Trail | Waste Type | Quantity in (kg) | Calorific Value (MJ/kg) | Total CV | Pressure (bar) | Flow of Steam (m/s) | Turbine Speed (RPM) | Voltage (V) |
|---|---|---|---|---|---|---|---|---|
| 1 | Wood Waste | 5 kg | 14 | 70 | 2.4 bar | 24 | 244 | 11.11 |
| 2 | Domestic Waste | 10 kg | 7 | 70 | 2.1 bar | 21 | 229 | 10.38 |
| 3 | Mixed Waste | 8 kg | 9 | 72 | 2.5 bar | 25 | 250 | 11.58 |

**Cost Estimation**

The financial feasibility of the fabricated model is evaluated through material procurement and fabrication operation costs.

*Material Cost*

***Table 2.*** *Material Cost Estimation.*

| Sr. No. | Name of Parts | Material | Qty | Cost (INR) |
|---|---|---|---|---|
| 01 | Rod for shaft | M.S. | 01 | 300 |
| 02 | Hollow cylinder for water | M.S. | 01 | 1050 |
| 03 | Turbine Blade | SS | 6 | 600 |
| 04 | Turbine Housing | M.S. | 02 | 300 |
| 05 | Turbine Cover | MS | 01 | 400 |
| 06 | Bearing Housing in Turbine Housing | Housing | 02 | 660 |
| 07 | Nozzle Jet | CU | 01 | 100 |
| 08 | Steam Inlet Pipe | STD | 01 | 260 |
| 08 | Safety valve | Brass | 01 | 250 |
| 09 | Ball valve | STD | 01 | 200 |
| 10 | Turbine supports frame | M.S. | 01 | 1200 |
| 11 | Plate | M.S. | 01 | 500 |
| 12 | Heater | STD | 01 | 300 |
| 13 | Wires | STD | 01 | 200 |
| 16 | Pressure gauge | Std | 1 | 450 |
| 20 | Pulley | Std | 1 | 450 |
| 21 | Dynamo | Std | 1 | 150 |
| **Total** | | | | **7370** |

*Operation Cost*

***Table 3.*** *Operation and Machining Cost Estimation.*

| Sr. No. | Operation | Hours | Rate | Labour Amount (INR) |
|---|---|---|---|---|
| 1 | Turning | 5 | 150 | 750 |
| 2 | Drilling | 7 | 100 | 700 |
| 3 | Welding | 12 | 175 | 2100 |
| 4 | Grinding | 3 | 60 | 180 |
| 5 | Tapping | 3 | 40 | 120 |
| 6 | Cutting | 8 | 40 | 320 |
| 7 | Assembly | 2 | 100 | 200 |
| 8 | Painting | 2 | 175 | 350 |
| **Total** | | | | **4720** |

Total project cost = Material cost + Operation cost Total project cost =7370+4720

Total project cost =12090

**Future Scope**

- Pollution Control Integration: Implementation of electrostatic precipitators, selective catalytic reduction (SCR) systems, and flue gas desulfurization units to capture particulate matter and neutralize gaseous pollutants .

- Advanced Sorting & Pre-treatment: Integration of optical sorting, eddy current separators, shredders, and pelletizers to improve feedstock consistency, lower moisture content, and promote circular economy material recovery.

## Conclusion

This study successfully designed, fabricated, and experimentally validated a small-scale municipal solid waste-to-energy conversion model. The setup effectively processes dry municipal waste fractions to produce steam, driving a turbine-generator assembly to generate stable electrical output voltages between 10.38 V and 11.58 V. The economic analysis indicates a highly cost-effective total project investment of INR 12,090, establishing its viability for decentralized renewable energy generation and sustainable waste management education.

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