A Review on Waste-to-Electricity Generation for Sustainable Power and Waste Management

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Abstract: Sustainability in developing and industrialized nations alike. The rapid increase in municipal solid waste (MSW) generation, driven by urbanization and population growth, presents a dual challenge of environmental pollution and energy scarcity. The development and implementation of a waste-to-electricity generator system that harnesses energy from organic and non-recyclable waste materials through controlled thermal and biological processes. The system integrates incineration, anaerobic digestion, or gasification technologies, depending on waste composition, to convert waste into usable energy in the form of electricity. The generator is designed to operate efficiently with minimal emissions, incorporating advanced filtration and energy recovery mechanisms to ensure compliance with environmental standards. The study also analyzes energy output, efficiency metrics, and carbon footprint reduction achieved through different configurations. The proposed waste-to-electricity model not only offers a sustainable waste management solution but also contributes to decentralized power generation and reduced dependence on fossil fuels. This research highlights the potential of waste-to-energy conversion as a viable component of circular economic strategies, promoting energy resilience and environmental.

I. INTRODUCTION

1. Sustainable Solution: Waste-to-electricity (WtE) generation offers a sustainable approach to waste management and energy production.
2. Waste Reduction: WtE technologies can significantly reduce the volume of waste sent to landfills.
3. Renewable Energy Source: Waste can be a reliable and consistent source of renewable energy.
4. Greenhouse Gas Reduction: WtE generation can help mitigate climate change by reducing greenhouse gas emissions.
5. Clean Energy: WtE can generate clean energy, reducing dependence on fossil fuels.
6. Waste Management: WtE promotes sustainable waste management practices, encouraging waste reduction and recycling.
7. Technologies: Various technologies, including incineration, pyrolysis, and anaerobic digestion, can be used for WtE generation.
8. 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.

1.2 TYPES OF METHODS USED:

1. Incineration: Burning waste to produce heat, which is then converted into electricity.
2. Pyrolysis: Thermal decomposition of waste in the absence of oxygen, producing fuels or energy.
3. Anaerobic Digestion: Microbial breakdown of organic waste, producing biogas that can be used to generate electricity.
4. Gasification: Converting waste into a synthesis gas (syngas) that can be used to generate electricity.

1.3 PROCESS INVOLVED:

1. Waste Collection: Collecting and sorting waste materials.
2. Pre-treatment: Preparing waste for energy conversion (e.g., shredding, sorting).
3. Energy Conversion: Converting waste into energy through incineration, pyrolysis, anaerobic digestion, or gasification.

4. Power Generation: Generating electricity or heat from the energy converted from waste.
5. Ash Management: Managing ash residues from the energy conversion process.

1.4 USES:
1. Electricity Generation: WtE can provide a reliable source of renewable energy.
2. Heat Production: WtE can produce heat for industrial or residential use.
3. Waste Management: WtE can reduce the volume of waste sent to landfills.

1.5 BENEFITS:
1. Renewable Energy Source: WtE can reduce dependence on fossil fuels.
2. Waste Reduction: WtE can minimize the environmental impacts associated with landfills.
3. Greenhouse Gas Reduction: WtE can help mitigate climate change by reducing greenhouse gas emissions.
4. Energy Security: WtE can enhance energy security by providing a local source of energy.

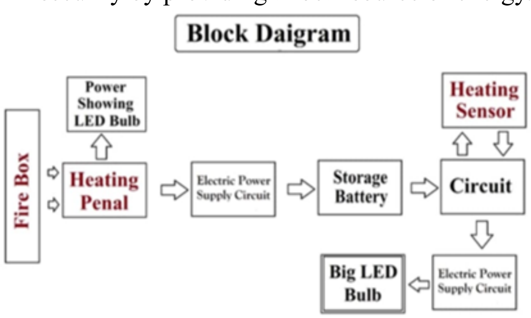

Fig: Block diagram

II. LITERATURE REVIEW

Komal Bhagwan Bodke, et.al., [1], this paper shows the Electricity generation from municipal solid waste was demonstrated using a prototype with heating panels, power booster circuits, batteries, and pollution control units. Waste combustion powered LED bulbs while reducing landfill volume and greenhouse gas emissions. Highlights sustainable, small-scale, and adaptable waste-to-energy solutions with environmental and economic benefits.

Maulana Gilar Nugraha et.al., [2], this paper shows the Simulation of Indonesia's municipal solid waste conversion via air, steam, plasma gasification, and incineration evaluated electricity output and emissions using Aspen Plus®. Gasification produced 15–27 MW, outperforming incineration. Study guides sustainable WtE strategies balancing energy yield with emission control for regional adaptation and renewable energy targets.

Paweł Kazimierski, et.al., [3], this paper shows the Energy recovery from leather tannery waste was assessed using combustion, pyrolysis, and gasification. Combustion achieved 94% efficiency, powering up to 40% of electricity demand via Organic Rankine Cycle integration. Demonstrates closed-loop, industrial-scale waste-to-energy solutions with minimal environmental hazards and support for circular economy principles.

David Chijioke Agha, et.al., [4], this paper shows the Plastic waste collected from a university campus was converted into electricity using calorific analysis. Average net calorific value of 15.23 MJ/kg generated 1.53 kWh/day. Highlights the feasibility of campus-scale waste-to-energy applications, reducing landfill reliance, greenhouse gas emissions, and supporting sustainable energy practices.

Nikesh Adhikari, et.al., [5], this paper shows the Electricity generation from municipal solid waste was demonstrated using heating panels, batteries, and filtration systems. Burning 200 g of paper/cloth produced 0.171 kWh, reducing landfill use while ensuring minimal emissions. Study confirms practical and eco-friendly small-scale waste-to-energy solutions with potential financial benefits for renewable electricity generation.

Shankar Reddy, et.al., [6], Electricity generation from plastic, rubber, paper, and wood was achieved using a waste-to-energy model with heating panels and rechargeable batteries. Combustion heat was converted to electricity and LED bulbs were powered while minimizing pollution using filters and water purifiers. Demonstrates sustainable local waste management, renewable energy production, and environmental benefits.

Suhas Bagel, et.al., [7], Electricity was produced by thermal waste-to-energy using combustion-generated steam to drive turbines. Waste from homes and industries was shredded, burned, and converted to electricity, stored in batteries, and monitored via LEDs. Pollution was minimized with filters, highlighting renewable energy generation, landfill reduction, and sustainable community-scale applications.

Nagraj Kumbar, et.al., [8], Municipal solid waste was converted into electricity through heating panels and thermoelectric generators. Combustion of sorted MSW generated 25–30 W from 15 g of waste, stored in batteries, and safely used to power LED bulbs. Pollution control and environmental measures demonstrated a practical small-scale renewable energy approach.

Prof. Munde N. S., et.al., [9], Electricity generation from plastic, rubber, and household waste was achieved using heating panels, boosting coils, and battery storage. Experimental results confirmed efficient power conversion, reduced CO_2, NO_2, SO_2 emissions, and decreased landfill dependency, providing a sustainable renewable energy model for India.

Dr. Manik Deosarkar, et.al., [10], Waste-to-energy processes including incineration and gasification converted municipal solid waste into electricity using boosting circuits, heating panels, and batteries. System reduced hazardous emissions, recovered usable energy, and supported sustainable energy supply while addressing waste management challenges.

Prof. Sushama Patwardhan, et.al., [11], Waste materials were incinerated and heat energy captured via heating panels to generate electricity, stored in batteries, and displayed through LEDs. Carbon collection plates and sensors minimized emissions, demonstrating practical, safe, and sustainable waste-to-electricity solutions for small communities.

Tamboli Faiz, et.al., [12], Electricity and fuel were produced from waste papers and plastics using incineration and pyrolysis. Heating panels generated electricity for LEDs while pyrolysis converted 1 kg of plastic into 600–750 ml of fuel. Demonstrates efficient, eco-friendly, dual-purpose waste-to-energy applications for sustainable resource management.

Asst. Prof. Vicky Chaudhari, et.al., [13], Solid waste including municipal, agricultural, and industrial residues was converted into electricity via incineration, gasification, and anaerobic digestion. Heating panels captured waste heat, stored in batteries, powering systems while carbon capture and filters reduced emissions, supporting sustainable energy and waste management.

Vaibhav V. Mainkar, et.al., [14], Plastic waste was converted into electricity and liquid fuel using pyrolysis and heating panels. Combustion powered LEDs while pyrolysis generated 600–750 ml fuel per kilogram. Demonstrates a sustainable solution for reducing plastic pollution, providing renewable energy, and substituting fossil fuels.

Ahmed Rida Galaly, et.al., [15], Plasma gasification was used to treat plastic waste in Makkah, Saudi Arabia, converting it into pyrolysis oil, syngas, and slag with 81% efficiency. About 3.17×10^5 tons of oil were recovered, generating 12.55×10^9 MJ of energy. The study showed high economic returns (80% ROI), short payback (1.2 years), and minimized environmental pollution, supporting Saudi Arabia's 2030 sustainability goals.

Manish Kumar, et.al., [16], Electricity was generated from waste materials like plastic, paper, and rubber using a Zaar box, heating panels, and battery storage. A heating sensor regulated output while water-based filters collected carbon particles. The prototype demonstrated a low-cost, practical method for small-scale waste-to-energy conversion.

Harshit Sharma, et.al., [17], Waste materials were incinerated to produce heat, which was converted into electricity via heating panels and stored in batteries. Smoke passed through a water filter to reduce emissions. The system proved feasible for small-scale renewable electricity generation, offering environmental benefits and waste management solutions.

Shashank Sharma, et.al., [18], Electricity was generated from municipal and industrial solid waste using heating panels and batteries, with carbon capture filters reducing emissions. The system demonstrated sustainable energy recovery while minimizing air pollution. Applications included residential, industrial, and agricultural settings, showing scalability and environmental benefits.

Sushmita Deb, et.al., [19], An Arduino-based thermoelectric generator converted heat from burning waste (plastic, paper, rubber, e-waste) into electricity, stored in batteries and powering loads. Catalytic converters and filters reduced emissions, while the Arduino controlled optimal operation. The system was cost-effective, eco-friendly, and scalable for small- to large-scale applications.

S.C. Dighe, et.al., [20], Waste materials like plastics and paper were burned in a Zaar box to generate heat, which was converted into electricity via heating panels and stored in batteries. LED bulbs demonstrated real-time electricity generation. The project provided a low-cost, practical method for supplementing electricity while managing waste.

Jesse Sarpong-Mensah, [21] Energy was generated from municipal solid waste plastics via pyrolysis, producing syngas, bio-oil, and biochar. Clean syngas powered CHP systems, while bio-oil and biochar were utilized for energy and agricultural purposes. The study showed reduced landfill waste, lower greenhouse gas emissions, and a sustainable alternative to fossil fuels.

Apsara H. K., et.al., [22], Plastic waste was converted into electricity using heating panels, sensors, and battery storage, demonstrating about 95% efficiency. LED indicators showed real-time generation, and small-scale experiments proved cost-effective and reliable. The system addressed energy shortages while providing an environmentally friendly waste management solution.

Mrs. Kalpana S., et.al., [23], Solid waste including plastics, paper, and rubber was burnt in a firebox to generate heat, which was converted to electricity using heating panels and stored in batteries. LED bulbs demonstrated output while catalytic converters and filters minimized emissions. The system proved cost-effective, eco-friendly, and suitable for small-scale energy recovery while reducing landfill needs.

Neha Rajas, et.al., [24], Electricity was generated from solid waste using incineration, while algae-based water purification produced biodiesel as a by-product. Thermoelectric generators and solar panels converted heat into electricity, stored and demonstrated via LEDs. The dual system offered sustainable, low-cost energy production while addressing waste management and pollution control.

Rohit Patil, et.al., [25], Waste materials like plastic and rubber were burnt to produce heat, converted into electricity through heating panels and sensors. Batteries stored the electricity, and LED indicators showed system performance. The method minimized harmful gas emissions, saved land from waste disposal, and provided a low-cost, eco-friendly energy solution for households and industry.

P.M. Pujari, et.al., [26], Plastic and other waste materials were incinerated to generate heat, converted to electricity via heating panels, and stored in batteries. Proximate and ultimate analyses confirmed energy potential, while filters minimized pollution. The system demonstrated sustainable electricity generation suitable for domestic, agricultural, and industrial applications.

K. Vijay Kumar, et.al., [27], Low-grade waste like plastics and rubber was converted to electricity using thermoelectric panels and DC-DC converters, powering LEDs. Pollution was reduced using carbon filters, and batteries stored the energy. The system offered an eco-friendly, scalable, low-cost solution for decentralized energy access and small-scale applications.

O. J. Olujobi, et.al., [28], Organic waste in Nigeria was assessed for electricity generation, evaluating legal frameworks and international best practices. Anaerobic digestion, gasification, and steam cycle technologies were explored for converting biomass to power. Findings indicated that integrated regulations and incentives could enable sustainable waste-to-electricity systems, reducing emissions and enhancing energy security.

Titus O. Ajewole, et.al., [29], Blended cocoa and kolanut farm residues were converted to bioethanol, mixed with gasoline, and used to fuel a spark ignition engine for off-grid electricity generation. Engine torque and generator output improved with the bioethanol blend, providing stable electricity for microgrid applications. The study demonstrated a practical method for utilizing agricultural waste for sustainable energy in rural regions.

A. Pandey, et.al., [31], Waste to Energy: Generation of Electricity Using Waste Materials. International Journal of Creative Research Thoughts (IJCRT), India. The study proposes electricity generation from solid waste in India, reducing emissions (CO_2, CO, SO_2, NO_2, Hg) and reliance on fossil fuels. Waste is collected, calorific value calculated, and burned in controlled setups to produce electricity. A compact demonstration powers 40–50 LEDs using a heating panel and Tesla coil. The process supports sustainable waste management and rising electricity demand.

Z. S. Mazhandu, et.al., [32], Application of Life Cycle Assessments in Waste Management. International Renewable and Sustainable Energy Conference (IRSEC), IEEE, South Africa. Highlights the limited adoption of Life Cycle Assessment (LCA) for municipal solid waste in Africa, emphasizing gasification's potential. Reviews LCA tools (SimaPro, GaBi, OpenLCA) and methodologies, showing gasification reduces global warming potential, toxicity, and resource depletion. Calls for regionspecific LCA studies to validate sustainable waste-to-energy practices in Africa.

M. Nirmala and K. Malarvizhi, [33] Solar Powered IoT Based Smart Solid Waste Management System. International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA), IEEE, India.Introduces a solar-powered, IoT-enabled waste pyrolysis system using ultrasonic sensors, PIC microcontroller, and MOSFET-controlled induction heating. Waste levels regulate heating dynamically; data is monitored remotely via Wi-Fi. The system automates decentralized solid waste management, reduces pollution, and leverages solar energy efficiently.

A. V. Badikana, A. K. M, M. Shunaif, and S. J, [34], Generation of Electricity Using Solid Waste. 45th Series Student Project Programme (SPP), India. Demonstrates electricity generation from municipal solid waste using heating panels and photovoltaic effects. Pollution control filters and catalytic converters minimize emissions. System powers LEDs, showing small-scale energy recovery and waste reduction, highlighting the dual benefit of energy generation and environmental sustainability.

M. R. S. Ramadhan, et.al., [35], Waste-to-Energy Potential Using Municipal Solid Waste as One Implementation of Jakarta Smart City. Serambi Engineering Journal, Indonesia. Evaluates WTE technologies (incineration, gasification, anaerobic digestion) for Jakarta MSW. Gasification combined with anaerobic digestion yields \~8.6 GWh/day, covering 9% of electricity demand. WTE reduces landfill use, emissions, and supports smart city initiatives, demonstrating feasibility for sustainable urban energy and waste management.

A. Rawool, et.al., [36], Utilization of Waste Plastic to Electricity Using Pyrolysis Process. International Research Journal of Engineering and Technology (IRJET), India. Portable pyrolysis unit converts waste plastic into electricity using zeolite catalyst. Gas drives a turbine to produce energy; by-products include pyrolysis oil and carbon black. The system is compact, eco-friendly, and cost-effective for small-scale energy generation, reducing plastic pollution while providing electricity.

Alzate, B. Restrepo-Cuestas, and Á. Jaramillo-Duque [37],Municipal Solid Waste as a Source of Electric Power Generation in Colombia: A Techno-Economic Evaluation under Different Scenarios. Resources, MDPI, Switzerland. Techno-economic analysis of MSW-based electricity in Colombian municipalities using incineration, gasification, anaerobic digestion, and landfill gas. Positive IRRs for larger municipalities (e.g., Pasto >13%). Policy incentives (Law 1715) improve viability. Small towns lack sufficient waste for economic feasibility. Environmental monitoring and public engagement are crucial for WTE success.

M. Mohammadi, S.-L. Jamsa-Jounela, and I. Harjunkoski [38] A Multi-Echelon Supply Chain Model for Sustainable Electricity Generation from Municipal Solid Waste. IFAC, Elsevier, Finland. Develops MILP model for multi-echelon MSW supply chain optimizing electricity generation via WtE. Integrates collection, separation, transport, conversion, and distribution, considering emissions. GAMS/CPLEX used for solution. Incineration yields highest profits; higher waste separation and conversion efficiency improve results. Model informs municipal planners on sustainable waste-to-energy networks.

D. MoyaClay, A. G. Lopez, and P. Kaparaju [39] Municipal Solid Waste as a Valuable Renewable Energy Resource: A Worldwide Opportunity of Energy Recovery by Using Waste-To-Energy Technologies. Energy Procedia, Elsevier, UK Reviews global WTE technologies (biological, thermal, landfill gas, biorefineries) for electricity, heat, and fuel from MSW. Case studies show effective ISWM-S in developed countries; developing nations face collection and disposal challenges. Highlights WTE as a renewable energy solution mitigating landfill and emissions issues worldwide.

A. Sz. Váradi, et.al., [40], Clean Electrical Power Generation from Municipal Solid Waste. IEEE, Hungary/Sweden/UK. Presents WTE plant combusting 180 t/day MSW at 1150°C to generate electricity (≥144 MWh/day), potable water, and industrial hot water. Waste Heat to Energy (WHE) recovers additional energy. System minimizes emissions, safely handles ash, and contributes to global warming mitigation.

III. CONCLUSION

In conclusion, waste-to-electricity generation offers a promising solution for sustainable power and waste management. By harnessing energy from waste, we can reduce greenhouse gas emissions, minimize landfill waste, and promote renewable energy production. Waste-to-electricity technologies can play a vital role in creating a more circular economy, reducing waste's environmental footprint while generating clean energy. The benefits of waste-to-electricity generation are numerous, including reducing dependence on fossil fuels, enhancing energy security, and promoting sustainable development. As the world transitions to a more sustainable future, waste-to-electricity generation can help mitigate climate change, ensure energy security, and promote sustainable development. By adopting waste-to-electricity solutions, we can create a cleaner, healthier environment for future generations while reducing waste management costs and promoting economic growth. Effective waste-to-electricity generation can have a significant impact on our environment, economy, and energy future.

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