Integrated Solid Waste Management System for Renewable Power Generation and Agricultural Usage

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Publication Date: 2025/09/27

Abstract: The rapid increase in municipal solid waste (MSW) has created significant challenges in waste disposal and environmental sustainability. An Integrated Solid Waste Management (ISWM) system offers a comprehensive solution by combining collection, segregation, processing, and utilization of waste to generate renewable energy and valuable by-products for agriculture. This project focuses on designing an ISWM system capable of converting biodegradable waste into biogas through anaerobic digestion, which can be used for electricity generation and agricultural pump operation. The process also produces nutrient-rich slurry that serves as an organic fertilizer, improving soil health and reducing dependence on chemical fertilizers. Non-biodegradable waste is segregated and directed towards recycling and safe disposal, minimizing landfill requirements. By integrating power generation with agricultural applications, this system enhances energy security, promotes sustainable farming practices, and reduces greenhouse gas emissions. The proposed solution not only addresses waste management challenges but also contributes to the circular economy by turning waste into a resource for clean energy and agricultural productivity.

Keywords: *Integrated Solid Waste Management (ISWM); Waste to Energy; Sustainable Agriculture; Energy Efficiency; Renewable Energy.*

How to Cite: Phule Pragati Bhagwan; Rajmane Prajkta Pandurang; Kashid Mukta Rajendra; K. N. Kazi (2025) Integrated Solid Waste Management System for Renewable Power Generation and Agricultural Usage. *International Journal of Innovative Science and Research Technology*, 10 (9), 1821-1825. https://doi.org/10.38124/ijisrt/25sep1107

I. INTRODUCTION

The rapid growth of population, urbanization, and industrialization has led to a dramatic increase in municipal solid waste (MSW) generation worldwide. Conventional methods of waste disposal, such as open dumping and uncontrolled landfilling, not only consume valuable land resources but also cause severe environmental pollution, groundwater contamination, and greenhouse gas emissions. These challenges demand a sustainable and efficient approach to waste management.

An Integrated Solid Waste Management (ISWM) system provides a comprehensive framework for handling solid waste through systematic segregation, collection, processing, recycling, energy recovery, and safe disposal. In this project, the focus is on utilizing the biodegradable fraction of waste for renewable power generation through anaerobic digestion, producing biogas as a clean energy source. The biogas can be used to generate electricity for various applications, including powering agricultural water pumps, thereby reducing dependence on conventional fossil fuels.

Additionally, the digestion process yields nutrient-rich slurry, which can be utilized as organic manure, enhancing soil fertility and reducing the use of chemical fertilizers. This integrated approach not only minimizes the environmental footprint of waste but also contributes to sustainable agriculture, energy security, and the circular economy by converting waste into a valuable resource.

➢ *Objective*

- Promote Waste Segregation: Ensure proper separation of wet, dry, and inert waste at the source for effective processing.
- Generate Renewable Energy: Convert organic waste into biogas or electricity to power irrigation pumps, rural electrification, or local grids.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25sep1107

- Produce Organic Fertilizer: Utilize digestate/compost to create nutrient-rich manure that enhances soil fertility and supports sustainable farming.
- Reduce Landfill Burden: Minimize the volume of waste sent to landfills, lowering methane emissions and land pollution.
- Encourage Resource Recovery: Recover energy, compost, and recyclables to support a circular economy.
- Support Farmers: Provide affordable energy and bio-fertilizers to boost agricultural productivity and reduce dependency on chemical inputs.
- Protect Environment: Lower greenhouse gas emissions, reduce groundwater contamination, and improve overall sanitation.
- Promote Community Participation: Involve local stakeholders and raise awareness for long-term success of the system.
- Achieve Economic Viability: Create jobs, generate revenue from energy and compost sales, and ensure financial sustainability.

➢ *Features of Teg*

- Integrated Approach: Combines waste collection, segregation, processing, and reuse in a single system.
- Renewable Energy Generation: Produces biogas, electricity, or heat from organic waste.
- Agricultural Support: Supplies organic compost or digestate as a bio-fertilizer to improve soil fertility.
- Resource Recovery: Maximizes recycling of plastics, metals, paper, and converts dry waste into RDF/fuel.
- Pollution Control: Reduces landfill dumping, leachate, foul odour, and greenhouse gas emissions.
- Scalability: Can be implemented at household, community, or city level depending on available waste quantity.
- Cost-Effective Solution: Reduces energy and fertilizer costs for farmers and municipalities.
- Eco-Friendly: Promotes circular economy and supports sustainable development goals (SDGs).
- Employment Generation: Creates local jobs in waste collection, sorting, composting, and energy plant operations.
- Technology Flexibility: Allows combination of anaerobic digestion, composting, gasification, pyrolysis as per waste composition.

II. CONCEPT AND METHODOLOGY

➢ *Block Diagram:*

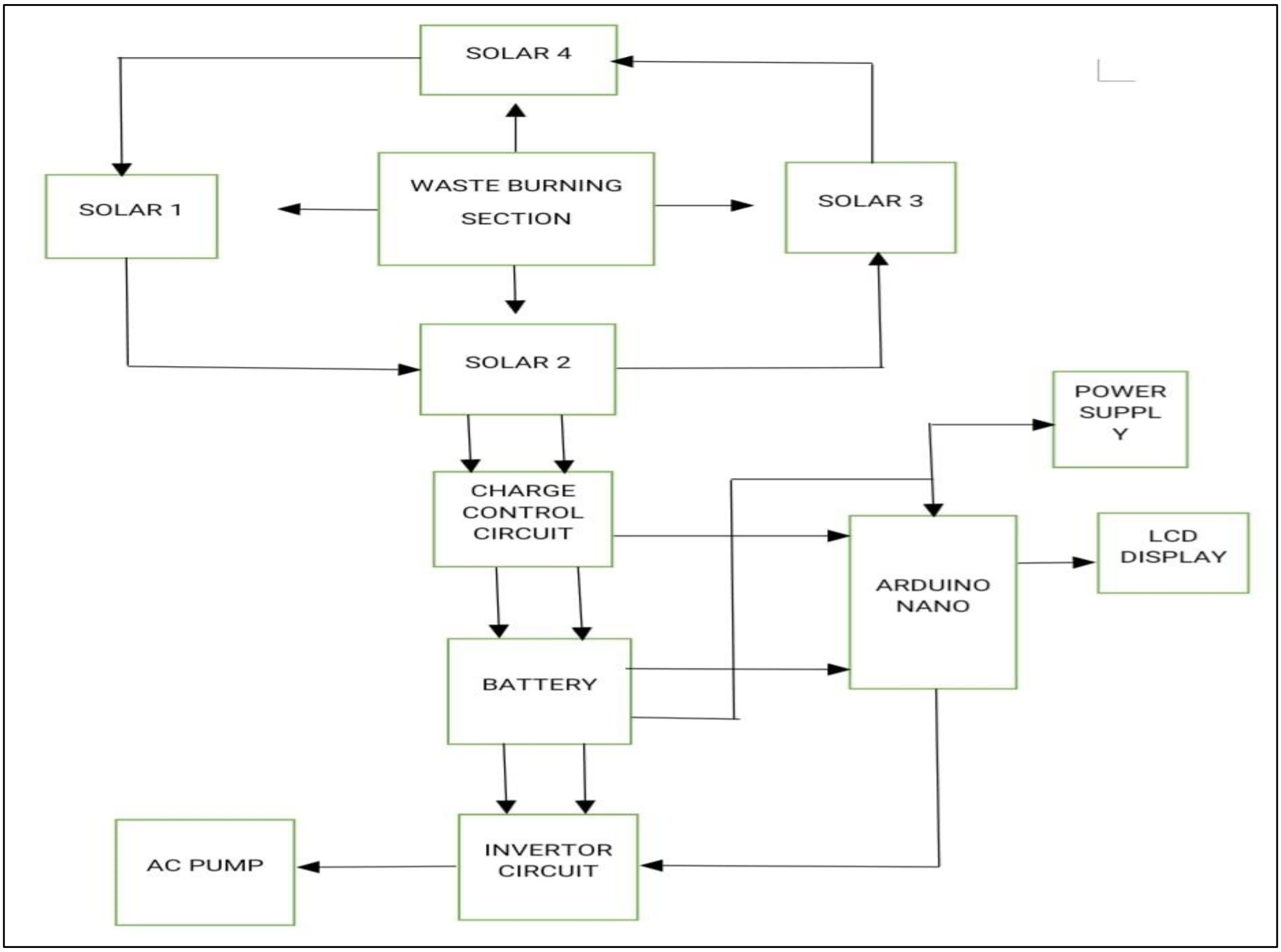

Fig 1 Electricity Generation from Waste Material

➢ *Description of the System*

- *Solar Panels (Solar-1, Solar-2, Solar-3, Solar-4):*
  Multiple solar panels are used to capture solar energy.

✓ Solar-1 & Solar-3: Supply direct power to the waste burning section, ensuring continuous heat for burning operations.
✓ Solar-4: Supports the waste burning process and helps maintain energy balance.
✓ Solar-2: Directly feeds into the charge control circuit to manage battery charging.

- *Waste Burning Section:*

Waste materials are burned in this section to produce heat/energy. The energy may be used to generate additional electricity (through a thermoelectric generator or steam turbine setup) or assist in maintaining battery charge.

- *Charge Control Circuit:*

This circuit regulates the charging of batteries to prevent overcharging or deep discharging, ensuring battery health and stable operation.

- *Battery Bank:*

Stores the energy generated from solar panels and waste burning. This stored energy acts as a backup power source for periods without sunlight or waste input.

- *Arduino Nano + LCD Display:*

The Arduino Nano is the microcontroller that monitors system parameters like battery voltage, current, power generated, and power consumed. The LCD display shows real-time status for user awareness.

- *Inverter Circuit:*

Converts stored DC power from the batteries into AC power, making it suitable for operating the AC water pump.

- *AC Pump:*

The final load that is powered by this system. It is used for pumping water for irrigation purposes.

- *Power Supply for Control System:*

Provides stable power to the Arduino Nano and control circuitry for smooth system operation.

➢ *Benefits*

- Environment-Friendly – lowers greenhouse gas emissions.
- Generates Renewable Power – clean energy from biogas for farm use.
- Ensures Reliable Irrigation – uninterrupted power for pumps.
- Improves Soil Health – provides nutrient-rich bio-fertilizer.
- Cost Savings – cuts electricity and diesel expenses.
- Cleaner Communities – promotes better hygiene and sanitation.
- Job Creation – employment in collection, operation, and maintenance.
- Promotes Circular Economy – converts waste into energy and resources.
- Supports Sustainable Farming – boosts productivity with eco-friendly practices.

➢ *Scope of the Study*

- Assessment of Waste Generation: Study the quantity and type of solid waste available (organic, recyclable, inert) in the target area to evaluate its potential for energy production.
- Technology Selection: Identify and compare suitable waste-to-energy technologies (e.g., anaerobic digestion, biogas engine, gasifier) for optimal power generation.
- System Design & Integration: Design an integrated system that collects, processes, and converts waste into renewable energy, then connects it to agricultural pumps for irrigation.
- Energy Utilization Analysis: Estimate power generation capacity, pump operating hours, and potential savings in grid power or diesel consumption.
- Environmental Impact Study: Analyze reduction in landfill waste, greenhouse gas emissions, and improvement in soil health through digestate use.
- Economic Feasibility: Evaluate the cost of installation, operation, maintenance, and payback period compared to conventional energy sources.
- Social & Community Benefits: Study the impact on local communities, including job creation, sanitation improvement, and awareness about waste segregation.
- Scalability & Future Expansion: Explore the potential for scaling the system to larger capacities or replicating it in other rural/agricultural regions.

➢ *Advantages*

- Renewable Energy Generation: Converts biodegradable waste into biogas, providing a continuous and eco-friendly source of power.
- Cost-Effective Solution: Reduces farmers' dependence on expensive diesel or grid electricity for irrigation.
- Waste Reduction: Minimizes landfill waste by efficiently utilizing organic waste for energy production.
- Environmental Protection: Lowers greenhouse gas emissions and prevents soil and water pollution caused by improper waste disposal.
- Resource Recovery: Produces nutrient-rich bio-slurry that can be used as an organic fertilizer, improving soil fertility.
- Energy Independence: Promotes self-sufficiency in rural communities by offering decentralized power generation.
- Employment Opportunities: Creates jobs in waste collection, segregation, and biogas plant operations.
- Sustainability: Supports the circular economy by turning waste into a valuable resource for energy and agriculture.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25sep1107

III. DISADVANTAGES

- *High Initial Investment:*

  Setting up a biogas plant and power generation unit requires significant capital, which may not be affordable for small farmers without subsidies.

- *Skilled Operation & Maintenance:*

  The system requires trained personnel for proper operation, regular maintenance, and troubleshooting.

- *Feedstock Dependency:*

  Continuous and adequate supply of biodegradable waste is essential; seasonal variations in waste generation may affect energy output.

- *Space Requirement:*

  Installation of biogas digesters and storage units requires land, which may be limited in densely populated or small farming areas.

- *Technical Challenges:*

  Gas leakage, digester failure, or low biogas yield can occur if the system is not designed or maintained properly.

- *Odor & Hygiene Issues:*

  Improper handling of waste or digestate can lead to foul smell and health concerns.

- *Economic Viability:*

  Payback period can be long without financial incentives, making it less attractive to farmers with low income.

- *Dependency on Community Participation:*

  Success depends on consistent waste segregation, collection, and cooperation from the local community.

IV. APPLICATIONS

- *Agricultural Pumping:*

  Reliable electricity generation from biogas can be used to power irrigation pumps, reducing dependency on grid power and diesel generators.

- *Rural Electrification:*

  Provides an off-grid renewable power solution for rural areas, improving energy access and supporting village development.

- *Waste-to-Energy Conversion:*

  Converts biodegradable waste into clean energy, reducing landfill waste and minimizing environmental pollution.

- *Sustainable Farming:*

  Produces nutrient-rich slurry as a by-product, which can be used as organic fertilizer, enhancing soil health and crop yield.

- *Community Waste Management:*

  Offers a decentralized solution for effective waste collection, segregation, and treatment at the local level.

- *Greenhouse Gas Reduction:*

  Helps in reducing methane emissions from open dumping of organic waste, contributing to climate change mitigation.

- *Economic Benefits:*

  Creates job opportunities in waste collection, plant operation, and maintenance, while reducing electricity costs for farmers.

V. CONCLUSION

The Integrated Solid Waste Management System for Renewable Energy and Powering Agricultural Pump Usage offers a sustainable solution to two major challenges effective waste disposal and reliable energy supply for agriculture. By converting biodegradable waste into biogas through anaerobic digestion, this system not only generates renewable energy but also provides nutrient-rich slurry that enhances soil fertility. The electricity produced can be used to run agricultural pumps, reducing dependence on grid electricity and diesel generators, which lowers operating costs for farmers and decreases carbon emissions. This approach contributes to waste minimization, circular economy practices, and rural energy security, making it a practical and eco-friendly model for rural development. With proper implementation, community participation, and support from government policies, the system has the potential to improve agricultural productivity, promote sustainable farming practices, and create local employment opportunities.

REFERENCES

[1]. A. Zafar, S. Ahmad, and M. Khan, “Optimizing dry waste incineration for energy recovery: Heat generation and environmental impact,” Waste Management Journal, vol. 45, no. 7, pp. 12-23, 2021.

[2]. X. Zhang, J. Liu, and Y. Wang, “Thermoelectric generators in waste-to-energy systems: Applications and advancements,” Renewable Energy Research Journal, vol. 38, no. 4, pp. 1125-1136, 2019.

[3]. Q. Chen, R. Huang, and L. Zhao, “Performance evaluation of TEC 12706 Peltier modules for energy harvesting,” Journal of Thermoelectric Research, vol. 54, no. 9, pp. 1021-1029, 2020.

[4]. D. Lopez, A. Martinez, and P. Garcia, “Environmental and economic assessment of waste-to-energy systems: A comparative study,” Energy and Environment Journal, vol. 61, no. 2, pp. 145-158, 2022.

[5]. J. D. Smith, L. M. Brown, and R. J. White, "Automated Waste Segregation System Using Arduino Uno R3," Journal of Environmental Engineering and Automation, vol. 12, no. 3, pp. 45-52, 2021.

[6]. P. S. Patel, V. Kumar, and S. Roy, "Eco Sort - Dry and Wet Waste Separator Using Arduino," International Journal of Sustainable Waste Management, vol. 15, no. 4, pp. 123-130, 2022.

[7]. A. S. Rao, K. P. Singh, and M. G. Nair, "Automatic Waste Segregator," International Journal of Waste Management and Recycling, vol. 10, no. 2, pp. 67-74, 2020.
[8]. Tchobanoglous, G., Theisen, H., & Vigil, S. (1993). Integrated Solid Waste Management: Engineering Principles and Management Issues. McGraw-Hill International Editions.
[9]. Sharholy, M., Ahmad, K., Mahmood, G., & Trivedi, R.C. (2008). "Municipal solid waste management in Indian cities – A review." Waste Management, 28(2), 459–467. https://doi.org/10.1016/j.wasman.2007.02.008
[10]. Singh, R.P., Tyagi, V.V., Allen, T., Ibrahim, M.H., & Kothari, R. (2011). "An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario." Renewable and Sustainable Energy Reviews, 15(9), 4797–4808. https://doi.org/10.1016/j.rser.2011.07.071
[11]. UNEP (2016). Global Waste Management Outlook. United Nations Environment Programme. Retrieved from https://www.unep.org/resources/report/global-waste-management-outlook
[12]. Ministry of New and Renewable Energy (MNRE), Government of India. (2023). Waste to Energy Programme – Guidelines and Reports. Retrieved from https://mnre.gov.in
[13]. Rada, E.C., Ragazzi, M., & Fedrizzi, P. (2013). "Energy recovery from MSW in the EU: A review of actual situation." Waste Management, 33(6), 1343–1358.
[14]. Gupta, S., Mohan, K., Prasad, R., Gupta, S., & Kansal, A. (1998). "Solid waste management in India: Options and opportunities." Resources, Conservation and Recycling, 24(2), 137–154.
[15]. ISWA (2020). Waste-to-Energy State-of-the-Art Report. International Solid Waste Association. Retrieved from https://www.iswa.org