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Techno-Economic Feasibility of Waste-to-Energy Plant for Municipal Solid Waste in Urban Areas

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Abstract- Municipal Solid Waste (MSW) management has become a major environmental challenge due to rapid urbanization, population growth, and changing consumption patterns. Traditional disposal methods such as open dumping and landfilling are no longer sustainable due to their adverse environmental and health impacts. Waste-to-Energy (WtE) technology offers a promising solution by converting waste into useful energy such as electricity, heat, and fuel. This study evaluates the techno-economic feasibility of implementing a WtE plant for municipal solid waste in urban areas, with a case study of Wanadongri Nagar Parishad, Nagpur. The research includes analysis of waste generation and composition, evaluation of WtE technologies such as incineration, gasification, pyrolysis, and anaerobic digestion, estimation of energy potential, and economic feasibility assessment. The results indicate that the study area generates approximately 25 tonnes per day of waste, with a high organic content suitable for biological treatment. The estimated energy generation potential is around 10,000–12,500 kWh/day. Economic analysis shows a feasible payback period of 6–8 years. Environmental benefits include significant reduction in landfill usage and greenhouse gas emissions. The study concludes that anaerobic digestion is the most suitable technology for the study area due to its efficiency, cost-effectiveness, and environmental advantages.

Keywords: Municipal Solid Waste (MSW), Waste-to-Energy (WtE), Techno-Economic Analysis, Incineration, Pyrolysis, Gasification, Anaerobic Digestion, Renewable Energy.

I. INTRODUCTION

Municipal solid waste (MSW) is defined as the unwanted or discarded material generated from day-to-day human activities, including residential, commercial, institutional, and industrial sources. It typically consists of biodegradable waste such as food and yard waste, along with non-biodegradable materials like plastics, paper, metals, and glass. With rapid population growth, urbanization, and industrial development, the generation of MSW has increased significantly across the world. According to global estimates, the total waste generation is expected to rise sharply and may reach nearly 3.8 billion tonnes by 2050, highlighting the urgent need for efficient and sustainable waste management systems [1][2].

In many developing countries, including India, waste management practices are still largely dependent on conventional methods such as open dumping and landfilling. These methods are not environmentally sustainable and create serious problems such as air pollution, groundwater contamination, soil degradation, and emission of greenhouse gases like methane. Improper waste disposal also leads to public health issues, including respiratory diseases, waterborne infections, and other environmental hazards. Therefore, effective management of municipal solid waste has become a major challenge for urban local bodies and policymakers [2][3].

In recent years, there has been a growing emphasis on adopting advanced and sustainable waste management techniques that not only reduce waste but also recover valuable resources. Waste-to-Energy (WtE) technology has emerged as a promising solution in this context. WtE refers to the process of converting waste materials into useful forms of energy such as electricity, heat, or fuel through various thermal and biological processes. Technologies such as incineration, gasification, pyrolysis, and anaerobic digestion are commonly used for energy recovery from waste [4].
The adoption of WtE technology offers multiple benefits. It significantly reduces the volume of waste (up to 80–90%), thereby decreasing the need for landfill space. It also contributes to renewable energy generation, reducing dependence on fossil fuels and supporting sustainable development goals. Furthermore, modern WtE plants are equipped with advanced pollution control systems, which help in minimizing environmental impacts and improving overall waste management efficiency [4][5].

Despite its advantages, the implementation of WtE technology requires careful evaluation of technical, economic, and environmental factors. The feasibility of such systems depends on waste composition, calorific value, investment cost, and local conditions. Therefore, conducting a detailed techno-economic analysis is essential before implementing WtE projects, especially in small and medium urban areas.

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In this context, the present study focuses on evaluating the techno-economic feasibility of a Waste-to-Energy plant for municipal solid waste management in an urban area, with a case study of Wanadongri Nagar Parishad, Nagpur. The study aims to provide a sustainable solution for waste management while contributing to energy generation and environmental protection.

II. LITERATURE REVIEW

Various researchers have extensively studied Waste-to-Energy (WtE) technologies and their techno-economic feasibility for municipal solid waste management. Studies by Ahmadi et al. (2025) and Abedin et al. (2025) highlight that thermal technologies such as incineration, gasification, and pyrolysis are suitable for high-calorific waste, while biological processes like anaerobic digestion are more effective for organic waste . Hossain et al. (2025) and Castillo-Leon et al. (2025) reported that WtE plants can be technically feasible but require strong policy support and financial incentives for economic viability . Soni et al. (2025) and Madhavaraj et al. (2025) emphasized that waste volume can be reduced by up to 90% and anaerobic digestion is highly suitable for organic-rich waste streams . Zeng et al. (2024) and Deng et al. (2024) demonstrated that advanced and hybrid systems improve efficiency and reduce environmental impacts . However, studies by Yakah et al. (2024), Dela Cruz et al. (2024), and Asthana (2019) identified challenges such as high capital cost, lack of proper waste segregation, and insufficient policy support, particularly in developing countries . Overall, the literature suggests that selection of appropriate WtE technology depends on waste characteristics, economic feasibility, and environmental considerations, highlighting the need for location-specific studies like the present research.

III. METHODOLOGY

The methodology adopted in this study includes:

3.1 Data Collection

1. Primary data through field survey
2. Secondary data from municipal records

Table 3.1: Study Area Details

Parameter	Value
Location	Wanadongri, Nagpur
Population	~50,000
Waste Generation	25 TPD
Type of Waste	Mixed (Organic + Plastic)

Figure 3.1: Wanadongri Map

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3.2 Waste Characterization

Table 3.2: Waste Composition in Wanadongri

Type of Waste	Percentage (%)
Organic	55–60%
Plastic	15–20%
Paper	10–15%
Others	10–15%

3.3 Technology Selection

1. Incineration
2. Gasification
3. Pyrolysis
4. Anaerobic Digestion

3.4 Energy Calculation

Energy = Waste × Calorific Value × Efficiency

3.5 Economic Analysis

1. Capital cost
2. Operating cost
3. Revenue
4. Payback period

IV. RESULTS AND DISCUSSION

4.1 Waste Generation

Parameter	Value
Population	50,000
Waste	25 TPD

4.2 Energy Potential

Estimated energy generation:
10,000–12,500 kWh/day

4.3 Technology Comparison

Technology	Efficiency	Cost	Suitability
Incineration	High	High	Mixed
Gasification	Medium	High	Dry
Pyrolysis	Medium	Medium	Plastic
Anaerobic Digestion	Low	Low	Organic

4.4 Economic Analysis

Parameter	Value
Capital Cost	₹15–20 Crore
Payback Period	6–8 years

Discussion:
The results obtained from the present study provide a comprehensive understanding of the municipal solid waste (MSW) scenario in Wanadongri and the feasibility of implementing Waste-to-Energy (WtE) technology. Based on the analysis, several key observations have been identified and discussed in detail below. Firstly, it is clearly observed that waste generation is continuously

increasing in the study area. This increase is mainly due to rapid population growth, urbanization, and changes in lifestyle patterns. As the standard of living improves and consumption of packaged goods increases, the quantity of waste generated also rises significantly. This creates pressure on the existing waste management system, which is often not capable of handling such large volumes efficiently. If this trend continues, it may lead to serious environmental and public health issues in the future, highlighting the need for advanced waste management solutions.

Secondly, the study shows that organic waste is the dominant component, constituting about 55–60% of the total waste generated. This high percentage of biodegradable waste indicates that biological treatment methods are more suitable for the study area. Organic waste can be effectively processed using anaerobic digestion, which converts it into biogas. This not only helps in reducing waste volume but also produces useful energy. The dominance of organic waste also reduces the dependency on high-cost thermal technologies, making the system more economical and environmentally friendly. Thirdly, the analysis confirms that the energy potential of municipal solid waste is significant. The estimated energy generation of around 10,000–12,500 kWh per day demonstrates that waste can be treated as a valuable resource rather than just a disposal problem. By utilizing this energy potential, it is possible to contribute to local electricity demand and reduce reliance on conventional fossil fuels. This supports the concept of sustainable development and promotes the use of renewable energy sources.

From an economic perspective, the study indicates that the WtE project is financially feasible. Although the initial investment required for setting up a WtE plant is relatively high, the revenue generated from energy production and savings in waste management costs make the project economically viable in the long term. The estimated payback period of 6–8 years is considered acceptable for infrastructure projects. Additionally, government incentives, subsidies, and proper policy support can further enhance the economic feasibility and encourage investment in such projects. Another important observation is that the environmental benefits of WtE technology are very high. The implementation of WtE systems significantly reduces the volume of waste, thereby minimizing the need for landfill space. It also helps in reducing greenhouse gas emissions, particularly methane, which is commonly produced in landfill sites. Furthermore, proper waste treatment prevents soil and groundwater contamination and improves overall environmental quality. These benefits make WtE technology a sustainable and eco-friendly solution for modern waste management.

In addition to these findings, the study also emphasizes the importance of proper waste segregation and efficient management practices. Without proper segregation at the source, the efficiency of WtE systems may be reduced. Therefore, public awareness and participation play a crucial role in the successful implementation of such projects.
In conclusion, the discussion clearly highlights that increasing waste generation, high organic content, significant energy potential, positive economic feasibility, and strong environmental benefits collectively support the adoption of Waste-to-Energy technology in Wanadongri. Among the available options, anaerobic digestion is identified as the most suitable technology due to its compatibility with the waste composition and cost-effectiveness. The study strongly recommends the implementation of WtE systems as a sustainable solution for effective municipal solid waste management.

V. CONCLUSION

The present study on the techno-economic feasibility of a Waste-to-Energy (WtE) plant for Wanadongri, Nagpur highlights the growing challenges of municipal solid waste management due to rapid urbanization and population growth. The area generates about 20–25 TPD of waste, with a high organic content (55–60%), making it suitable for biological treatment methods. Among the technologies studied, anaerobic digestion is found to be the most suitable due to its low cost, environmental benefits, and compatibility with organic waste, while incineration can be considered for mixed waste. The energy potential is significant, with an estimated generation of 10,000–12,500 kWh/day, showing that waste can be effectively utilized as a renewable energy source. The economic analysis confirms that the project is financially feasible, with a payback period of 6–8 years, and offers long-term benefits. Environmentally, WtE reduces landfill usage, lowers emissions, and improves overall sustainability. In conclusion, Waste-to-Energy technology is a practical and sustainable solution for urban waste management, and its implementation can improve environmental conditions while generating useful energy.

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