Advances in Energy and Materials Research https://jaem.qom.ac.ir/

Cost-Benefit Assessment of Incineration Solution for Municipal Solid Waste: a Case Study in Qom Province

Ali Marefat[✉1] and Ali Akbar Heidari [2]

1. Correspspinding authoer, Faculty of Environment, University of Tehran, Tehran, Iran. Email: ali.marefat@ut.ac.ir
2. Department of Chemical Engineering, University of Tafresh, Tafresh, Iran.

Article Info

Article type:
Research Article

Article history:
Received 18 Jun 2024
Received in revised form 27 Sep 2024
Accepted 3 Nov 2024
Published online 25 Dec 2024

Keywords:
Cost- benefit analysis; Waste to energy; Financial indicators; Incineration; Municipal solid waste.

ABSTRACT

Rapid urbanization has escalated the complexities of municipal solid waste management, particularly in cities like Qom, Iran, which generates approximately 600 tons of waste daily. This study investigates incineration-based waste-to-energy (WTE) systems as a sustainable solution to mitigate landfill dependency while producing renewable energy. Through a rigorous economic evaluation, we assess the viability of WTE implementation using key financial indicators, including Net Present Value (NPV), Internal Rate of Return (IRR), Levelized Cost of Energy (LCOE), and payback period. Our findings indicate that Qom's waste stream could yield approximately 10.6 MW of electricity through incineration, offering a promising avenue for sustainable waste management. However, the economic feasibility is hindered by high capital and operational costs, coupled with low electricity tariffs in Iran. The analysis reveals that a minimum gate fee of US$10.5 per ton is essential to achieve financial viability. Sensitivity analyses further identify the discount rate and electricity tariff as critical determinants of project profitability, while enhancements in energy conversion efficiency yield only marginal economic benefits. This study provides actionable insights for policymakers and investors, highlighting the economic challenges of deploying WTE systems in Qom and emphasizing the need for robust pricing mechanisms and supportive policy frameworks to ensure the financial and environmental sustainability of such initiatives.

Cite this article: Marefat, A. & Heidari, A. (2024). Cost-benefit assessment of incineration solution for municipal solid waste: a case study in qom province, *Advances in Energy and Materials Research*, *1* (4), 1-6. https://doi.org/10.22091/jaem.2025.12975.1024

DOI: 10.22091/jaem.2025.12975.1024
Publisher: University of Qom.

1. Introduction

The global rise in municipal solid waste (MSW) has prompted growing interest in sustainable waste management practices. Among these, waste-to-energy (WtE) incineration has become one of the most widely adopted solutions, particularly in developed countries [1,2]. According to the United Nations Environment Programme (UNEP), as of 2019, approximately 30% of MSW in East Asia, 25% in Europe, and 12% in North America is processed through incineration for energy recovery [3]. Currently, over 1,700 WtE plants operate worldwide, with Japan, France, Germany, and the United States hosting the majority [3]. The World Bank also reports that the incineration capacities in Japan and the United States each exceed 30 million tons annually [4].

In contrast, WtE incineration remains underutilized in many developing regions, including the Middle East. Nonetheless, some countries are beginning to invest in large-scale projects. For instance, the United Arab Emirates is constructing one of the world's largest WtE plants in Dubai, capable of treating 5,000 tons of waste per day and supplying electricity to 120,000 households [5]. Despite these advances, most Middle Eastern countries, including Iran, have yet to implement WtE technologies on a significant scale [6].

Qom Province, located in central Iran, produces around 600 tons of MSW daily. With a relatively high calorific value in its waste composition, Qom presents a promising case for the deployment of incineration technology. This approach could simultaneously alleviate the region's growing waste management challenges and contribute to renewable energy generation [7]. Beyond reducing dependence on landfilling [8], WtE incineration has the potential to decrease greenhouse gas emissions [9], minimize fossil fuel consumption [10], and manage non-recyclable waste effectively [11]. According to global projections, WtE technologies could generate up to 52 TWh of electricity by 2050, underscoring their role in a diversified renewable energy portfolio [3].

Although previous studies have examined the technical and environmental benefits of WtE systems, limited research has focused on the financial feasibility of such projects in Iran's economic context. Moreover, localized studies that incorporate sensitivity analyses to identify key investment drivers are scarce.

This study addresses this gap by evaluating the economic viability of implementing a WtE incineration plant in Qom. Using financial indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), Discounted Payback Period (DPBP), Levelized Cost of Electricity (LCOE), and Levelized Cost of Waste (LCOW), this research provides a comprehensive financial assessment. A sensitivity analysis further explores the impact of key variables—such as electricity tariffs, gate fees, and discount rates—on project profitability.

The findings aim to inform policymakers and investors about the economic barriers and opportunities associated with WtE development in Iran, offering data-driven insights for advancing sustainable waste management in the region.

2. Methods

2.1 Municipal solid waste in Qom

Qom Province, covering an area of 11,273 square kilometers and home to around 1.3 million people, is a major metropolitan region in Iran, located approximately 125 kilometers south of the capital, Tehran. The daily average generation of urban waste is about 600 tons. Table 1 represents the physical composition and lower calorific value of municipal solid waste in Qom [12].

Table 1. Composition and lower calorific value of municipal solid waste in Qom

Waste type	Glass	Wood	Plastic	Textiles	Paper and Cardboard	Food and yard waste	Metals	Inert	Total
Composition (%)	1.7	5.5	8.9	3.6	5	75	2	2	100
LCV (Kj/Kg)	-290	15000	25000	13000	12000	3000	-290	18000	6100

2.2. Energy Production Estimation

To estimate the quantitative electrical energy generation from an Incineration system, the equation (1) is used. In this equation, LHV_{waste}, M and 3.6 are the lower heating value of MSW (MJ/Kg), the amount of MSW that could be utilized for incineration ($tons/yr$), and conversion factor from MJ to kWh, respectively. Conversion efficiency (η_{INC}) is taken for incineration and is 25% [13].

$$E_{INC}(KWh/year) = \frac{LHV_{waste} \times M \times \eta_{INC}}{3.6} \tag{1}$$

2.3. Lower Heating Value (LHV) Estimation

Energy production through incineration relies on the lower heating value (LHV) of the various components in municipal solid waste. Table 1 and equation (2) are used to calculate the lower heating value of QOM urban waste. Where LHV_i and W_i are the calorific value and weight percentage of each fraction of urban waste, respectively.

$$LHV_{total} = \sum(LHV_i) \times (W_i) \tag{2}$$

2.4. Financial Model Development

A financial model was developed to assess the economic feasibility of incineration technology in Qom. This evaluation is based on key financial indicators, including net present value (NPV), internal rate of return (IRR), payback period (PBP), discounted payback period (DPBP), levelized cost of electricity (LCOE), and levelized cost of waste (LCOW). The following equations and definitions were used to calculate these indicators.

NPV is the equivalent of all cash inflows and outflows during the lifetime of a project at present, as shown in equation (3). In this equation, CAPEX and OPEX are capital expenditure (or initial investment) and operational expenditure, respectively.

$$NPV = \sum CAPEX + \frac{\sum OPEX}{(1+r)^n} \tag{3}$$

IRR is a discount rate that makes the NPV value equal to zero.

$$0 = \mathrm{I}_0 + \frac{\sum_{t=1}^{n} \mathrm{OPEX_t}}{(1+\mathrm{IRR})^t} \tag{4}$$

PBP is the required number of years to recover investment costs. However, DPBP is the years required to recover discounted investment costs.

LCOE demonstrates the minimum price at which electricity must be sold to reach the breakeven point at the end of project life (equation 4). Similarly, LCOW demonstrates the unit cost of the treated waste during the operational life of the WtE facilities (equation 5).

$$\mathrm{LCOE} = \frac{\mathrm{I}_0 + \sum_{t=1}^{n} \frac{\mathrm{OPEX}_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{\mathrm{E}_t}{(1+r)^t}} \tag{4}$$

$$\mathrm{LCOW} = \frac{\mathrm{I}_0 + \sum_{t=1}^{n} \frac{\mathrm{OPEX}_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{\mathrm{W}_t}{(1+r)^t}} \tag{5}$$

where

I_0: The initial investment cost

$OPEX_t$: The operation & maintenance costs in year t

r: The discounted rate

E_t: The total energy produced in year t (MWh)

W_t: The amount of total waste treated in year t

2.5. Financial assumptions

The following is used to facilitate the financial analysis. The numbers utilized in this paper are mostly derived from the studies done by the International Renewable Energy Agency (IRENA) and the reports published in the literature pertinent to Iran.

A. **Construction phase**: The design and construction phase are assumed to take 3 years.
B. **Operational life**: The paper considers 17 years of economic life, starting from the year 2027.
C. **Capacity factor**: The paper assumes an 85% capacity factor.
D. **Electricity sale tariff**: According to government regulations, the base electricity sale tariff for power plants that use waste as fuel is set at 5,000 Iranian tomans per kilowatt-hour (The exchange rate was assumed to be 80,000 Iranian tomans per U.S. dollar).
E. **Annual increase in electricity sales tariff**: According to the government legislation, based on the average annual increase in the exchange rate and the inflation rate, the sales tariff increases by 24.5% annually.
F. **Discounted rate**: This paper assumes a discounted rate equal to the bank interest rate in Iran, i.e., 25%.
G. **Capital Expenditure (CAPEX)**: The average CAPEX cost is assumed to be 7000 USD/kW [14].
H. **Operation and Maintenance Expenditure (OPEX)**: This paper assumes that OPEX accounts for 4% of total CAPEX cost [14].

3. Results and discussion

According to Equation 1, Qom Province has the potential to establish a waste-to-energy incineration plant with a capacity of 10.6 megawatts through its urban wastes. Table 2 represents initial investment costs (or CAPEX), annual operational and maintenance costs (or OPEX), and annual incomes. Based on the developed financial model, the construction of a waste-to-energy incineration plant in Qom Province requires an initial investment of USD 74 million. In addition, annual operation and maintenance costs are estimated at approximately USD 2.9 million. In return, considering electricity sales during the operational years and accounting for the time value of money as of early 2024, the total projected revenue from electricity sales over the plant's lifetime is estimated at around USD 80 million. However, when compared to other waste-to-energy technologies—such as gasification, anaerobic digestion, and landfill gas recovery—incineration proves to be a more expensive option for treating municipal waste, primarily due to its significantly higher capital (CAPEX) and operational (OPEX) costs [15] .

Table 2. Cash flow analysis of incineration technology

Discounted Cumulative cash flow	Cumulative cash flow	Cash flow	Electricity income	OPEX	CAPEX	Year
		(US$)				
-24,463,542	-24,463,542	-24,463,542			24,463,542	2024
-44,034,375	-48,927,083	-24,463,542			24,463,542	2025
-59,691,042	-73,390,625	-24,463,542			24,463,542	2026
-58,088,535	-70,260,730	3,129,895	6,065,520	2,935,625		2027
-56,209,470	-65,673,168	4,587,562	7,523,187	2,935,625		2028
-54,113,780	-59,277,631	6,395,536	9,331,161	2,935,625		2029
-51,849,380	-50,639,628	8,638,003	11,573,628	2,935,625		2030
-49,454,562	-39,220,247	11,419,381	14,355,006	2,935,625		2031
-46,959,928	-24,351,068	14,869,179	17,804,804	2,935,625		2032
-44,389,922	-5,203,035	19,148,034	22,083,659	2,935,625		2033
-41,764,067	19,252,149	24,455,184	27,390,809	2,935,625		2034

Discounted Cumulative cash flow	Cumulative cash flow	Cash flow	Electricity income	OPEX	CAPEX	Year
-39,097,945	50,289,898	31,037,749	33,973,374	2,935,625		2035
-36,403,987	89,492,136	39,202,238	42,137,863	2,935,625		2036
-33,692,107	138,820,956	49,328,820	52,264,445	2,935,625		2037
-30,970,199	200,709,980	61,889,023	64,824,648	2,935,625		2038
-28,244,546	278,177,678	77,467,698	80,403,323	2,935,625		2039
-25,520,143	374,967,922	96,790,244	99,725,869	2,935,625		2040
-22,800,951	495,724,310	120,756,388	123,692,013	2,935,625		2041
-20,090,107	646,206,392	150,482,082	153,417,707	2,935,625		2042
-17,390,088	833,557,854	187,351,462	190,287,087	2,935,625		2043

Table 3 presents the financial evaluation results for the incineration technology. As shown, the internal rate of return (IRR) is 21%, while the net present value (NPV), based on the current electricity tariff of \$0.05/kWh, is negative at –\$13.9 million. The discounted payback period (DPBP) also confirms that, under current economic conditions, the construction of the Qom incineration plant would not result in a return on investment. Therefore, incineration technology is not economically profitable to recover energy recovery. Furthermore, LCOE and LCOW reveal that energy recovery and waste treatment using incineration technology is extremely expensive [16-17]. Therefore, to make the construction of a waste-to-energy incineration plant in Qom economically viable, either the current electricity tariff must be increased, or additional revenue streams—such as a gate fee—should be considered. In waste management, a gate fee refers to the charge applied per ton of waste delivered and processed at the facility. It is worth noting that many researchers have emphasized the need for supplementary revenue streams in waste-to-energy projects, due to the significantly high capital and operational costs associated with this technology. For instance, a study on the development of a waste-to-energy plant in Oman concluded that, without considering carbon credits, the project would not be economically viable under the current electricity tariff [18]. Similarly, a study conducted in Colombia emphasized the importance of tax incentives to ensure the financial sustainability of such plants [19].

In this study, various gate fee levels were incorporated into the financial model as a supplementary revenue source alongside electricity sales, to determine the minimum gate fee required for the economic viability of a waste-to-energy plant in Qom. The aim of this analysis is to identify the fee that must be charged per ton of waste from citizens so that, in combination with electricity revenue, the project becomes financially feasible. According to the results presented in Table 4, for the construction of a waste-to-energy plant in Qom to be economically viable, citizens would need to pay a gate fee of \$10.5 per ton of waste generated. This amount, as a supplementary revenue source alongside income from electricity sales, would enable the investor to cover the capital and operational costs of the plant and bring the project to financial breakeven. Without this gate fee, relying solely on electricity sales at the current tariff would not provide sufficient financial justification for implementing the project. However, with a discounted payback period of 19 years, the project is unlikely to be attractive to investors unless additional financial incentives or supportive policies are introduced.

Table 3. Financial performance indicators for the incineration plant

Financial indicator	Value
NPV (USD)	-13,912,070
IRR (%)	21
PBP (Years)	7
DPBP (Years)	No return
LCOE (USD/KWh)	0.228
LCOW (USD/ton)	96.44

Table 4. Economic assessment of the incineration plant under different values of gate fee

Gate fee (\$/ton)	IRR (%)	NPV (USD)	PBP	DPBP
5	23	-6,980,619	6	No return
7	24	-3,514,893	6	No return
8	25	-1,782,031	6	No return
10	25	-49,168	6	No return
10.5	25	817,262.88	5	19
11	25	+1,683,694	5	19

3.1. Sensitivity analysis

Sensitivity analysis is a valuable method for identifying the key factors that influence a project's profitability [20]. In this study, five input parameters were selected for evaluation: electricity sale tariff, discount rate, facility waste processing capacity, capital expenditure (CAPEX), and operational expenditure (OPEX). Each parameter was varied by ±10% to observe its effect on the net present value (NPV) of the waste-to-energy (WtE) technologies.

Table 5 summarizes the impact of these changes. The results show that NPV has a strong positive correlation with the electricity tariff, since higher energy prices directly increase revenue from electricity sales. Conversely, increases in the discount rate and CAPEX reduce the NPV. A higher discount rate reduces the present value of future cash flows, making long-term projects less attractive. Similarly, higher CAPEX increases the initial investment burden, reducing overall profitability.

Changes in facility waste capacity and OPEX show relatively minor effects. While processing more waste could increase output and revenue, this change is limited by system capacity and efficiency. Likewise, small fluctuations in OPEX don't drastically alter profitability unless sustained over time. Among all variables, the discount rate has the most significant impact on NPV, underscoring how financial conditions and investor expectations heavily shape the economic feasibility of incineration projects.

Table 5. Effect of input parameters change on Incineration plant NPV (considering \$10.5 as gate fee)

Input parameters	-10% decrease	No change	+10% increase	sensitivity
Electricity tariff sale	-2,870,173	30,024,366	62,918,907	high
Discounted rate	131,395,323	30,024,366	-45,094,367	very high

Input parameters	-10% decrease	No change	+10% increase	sensitivity
Facility waste capacity	27,021,929	30,024,366	33,026,803	low
CAPEX	77,739,100	30,024,366	-17,690,367	high
OPEX	36,513,502	30,024,366	23,535,230	low

4. Conclusion

Incineration-based waste-to-energy (WTE) systems offer a sustainable and space-efficient solution for managing municipal solid waste while generating renewable energy. However, their adoption in regions like Qom, Iran, faces significant economic hurdles due to high capital, equipment, and operational costs. This study's financial analysis reveals that, even with an electricity tariff of $0.05 per kilowatt-hour, a WTE facility processing 600 tons of waste daily in Qom (population ~1.2 million) is not economically viable without additional revenue streams. A minimum gate fee of $10.5 per ton of waste, alongside electricity sales, is necessary to achieve financial sustainability.

Even with such measures, the projected financial metrics—Net Present Value (NPV) of $1.6 million, Internal Rate of Return (IRR) of 26%, and a 19-year payback period—suggest limited attractiveness for investors. Moreover, imposing gate fees on households is likely infeasible given Iran's current economic constraints and financial pressures on citizens. Consequently, investment in incineration-based WTE facilities is not advisable under present conditions. Instead, policymakers and stakeholders should prioritize more cost-effective and adaptable waste management strategies to address Qom's urban waste challenges effectively.

Conflict of interest

The authors declare no competing interests.

Acknowledgment

There is no acknowledgment for this manuscript.

Authorship Declaration

All authors have made substantial contributions to the conception, design, execution, or interpretation of the reported study. Each author has approved the final version of the manuscript and agrees to be accountable for all aspects of the work.

References

[1] Shah, H. H., Amin, M., & Pepe, F. (2023). Maximizing resource efficiency: Opportunities for energy recovery from municipal solid waste in Europe. Journal of Material Cycles and Waste Management, 25(6), 2766–2782

[2] Yan, M., Wibowo, H., Liu, Q., Cai, Y., Ar Rahim, D., & Yanjun, H. (2020). Municipal solid waste management and treatment in China. In H. Akkucuk (Ed.), Handbook of research on resource management for pollution and waste treatment (pp. 86–114). IGI Global.

[3] United Nations Environment Programme. (2019). Waste to energy: Considerations for informed decision-making. https://www.unep.org/resources/report/waste-energy-considerations-informed-decision-making

[4] Tabata, T., & Tsai, P. (2016). Heat supply from municipal solid waste incineration plants in Japan: Current situation and future challenges. Waste Management & Research, 34(2), 148–155. https://doi.org/10.1177/0734242X15617009

[5] Thabit, Q., Nassour, A., & Nelles, M. (2020). Potentiality of waste-to-energy sector coupling in the MENA region: Jordan as a case study. Energies, 13(11), 2786. https://doi.org/10.3390/en13112786

[6] Tsunematsu, M., Ishibashi, Y., Yukioka, K., Uchida, Y., Nakano, M., Takaoka, M., & Oshita, K. (2024). Behaviors and emission inventories of microplastics from various municipal solid waste incinerators in Japan. Journal of Material Cycles and Waste Management, 26(2), 692–707. https://doi.org/10.1007/s10163-023-01804-7

[7] Mao, J., Xu, Y., Wang, C., Zhao, Y., Wang, Y., Zhang, Z., ... & Liu, Z. (2024). Innovative dual-benefit recycling and sustainable management of municipal solid waste incineration fly ash via ultra-high performance concrete. Science of the Total Environment, 957, 177852. https://doi.org/10.1016/j.scitotenv.2024.177852

[8] Zhao, X.-G., Jiang, G.-W., Li, A., & Wang, L. (2016). Economic analysis of waste-to-energy industry in China. Waste Management, 48, 604–618. https://doi.org/10.1016/j.wasman.2015.10.014

[9] Zafar, A. M., Shahbaz, M., Rauf, A., Waqas, M., Khan, M. I., & Iqbal, M. (2024). Waste to energy feasibility, challenges, and perspective in municipal solid waste incineration and implementation: A case study for Pakistan. Chemical Engineering Journal Advances, 18, 100595. https://doi.org/10.1016/j.ceja.2024.100595

[10] Rouhi, K., Shahbazi, A., Karimi, S., & Ghanbari, M. (2024). Towards sustainable electricity generation: Evaluating carbon footprint in waste-to-energy plants for environmental mitigation in Iran. Energy Reports, 11, 2623–2632. https://doi.org/10.1016/j.egyr.2024.02.017

[11] Ferdan, T., Pavlas, M., Nevrlý, V., Šomplák, R., & Stehlík, P. (2018). Greenhouse gas emissions from thermal treatment of non-recyclable municipal waste. Frontiers of Chemical Science and Engineering, 12, 815–831. https://doi.org/10.1007/s11705-018-1761-4

[12] Ghafuri, Y., & Koohpaei, A. (2022). Risk characterisation and methods of improving practice for municipal waste management in disaster situations: A case study in Qom Province, Iran. Jàmbá: Journal of Disaster Risk Studies, 14(1), 1151. https://doi.org/10.1007/s10163-013-0154-5

[13] Gómez, A., Zubizarreta, J., Rodrigues, M., Dopazo, C., & Fueyo, N. (2010). Potential and cost of electricity generation from human and animal waste in Spain.

Renewable Energy, 35(2), 498–505. https://doi.org/10.1016/j.renene.2009.07.027
[14] International Renewable Energy Agency (IRENA). (2023). The cost of financing for renewable power: 2023 edition. https://www.irena.org/publications/2023/Jun/The-cost-of-financing-for-renewable-power-2023.
[15] Aleluia, J., & Ferrão, P. (2017). Assessing the costs of municipal solid waste treatment technologies in developing Asian countries. Waste Management, 69, 592–608. https://doi.org/10.1016/j.wasman.2017.08.047
[16] Talang, R. P. N., & Sirivithayapakorn, S. (2021). Environmental and financial assessments of open burning, open dumping and integrated municipal solid waste disposal schemes among different income groups. Journal of Cleaner Production, 312, 127761. https://doi.org/10.1016/j.jclepro.2021.127761
[17] Rezaei, M., Yousefi, H., Ghanbari, M., & Zarei, A. (2018). Electric power generation from municipal solid waste: A techno-economical assessment under different scenarios in Iran. Energy, 152, 46–56. https://doi.org/10.1016/j.energy.2017.10.109
[18] Abushammala, M. F., & Qazi, W. A. (2021). Financial feasibility of waste-to-energy technologies for municipal solid waste management in Muscat, Sultanate of Oman. Clean Technologies and Environmental Policy, 23, 2011–2023. https://doi.org/10.1007/s10098-021-02099-8
[19] Alzate-Arias, S., Jaramillo-Duque, Á., Villada, F., & Restrepo-Baena, O. (2018). Assessment of government incentives for energy from waste in Colombia. Sustainability, 10(4), 1294. https://doi.org/10.3390/su10041294
[20] Ahmed, M. M., Rahman, M. M., Hossain, M. S., Uddin, M. T., & Kabir, E. (2024). Prospect of waste-to-energy technologies in selected regions of lower and lower-middle-income countries of the world. Journal of Cleaner Production, 450, 142006. https://doi.org/10.1016/j.jclepro.2024.142006