



Economic and Environmental Feasibility Analyses of Waste-to-Energy Generation under Different Technologies for Dhaka City

Md. Abu Bakkar Siddique^{1,2,✉}, Khandker Farid Uddin Ahmed¹, Islam Mohammed Mahbubul³

¹Department of Mathematics, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh

²Department of Mathematics, Dhaka Commerce College, Dhaka, Bangladesh

³Institute of Energy Engineering, Dhaka University of Engineering & Technology, Gazipur, Bangladesh

Received December 20, 2025

Revised May 21, 2026

Accepted July 3, 2026

Published online: September 18, 2026

Keywords

Waste-to-energy
Economic assessment
Anaerobic digestion
Landfill gas to energy
Incineration
Gasification

Abstract: Dhaka city is facing several challenges to manage daily generated waste and fulfilling electricity demand of huge population. The aim of the study is to evaluate the economic and environmental feasibility of waste-to-energy (WtE) systems such as anaerobic digestion (AD), landfill gas to energy (LFGTE), incineration (INC), and gasification (GAS) technologies for Dhaka city using life cycle costing (LCC) methodology. The economic assessment reveal that all the WtE systems are economically feasible except LFGTE technology because of net present value (NPV) negative (−BDT 3,531/ton) and lowest internal rate of return (IRR) (8% < discount rate). But, LFGTE technology will be an economic option for electricity price greater than BDT 20.72/kWh. The results also show that INC is an optimal WtE system based on lowest LCC (BDT 22,914/ton), levelized cost of energy (LCOE) (BDT 4.49/kWh), payback period (PBP) (1.64 year), and highest IRR (61%) but AD and GAS technology are moderately economic option. The environmental assessment shows that INC technology has the highest (508 kg CO₂ eq/ton waste), AD has the lowest (214 kg CO₂ eq/ton waste) and GAS has moderate (344 kg CO₂ eq/ton waste) carbon dioxide and other toxic gas emissions rate among other technologies. This study will play a vital role in providing information to implement economically feasible WtE systems in Dhaka city.

© 2026 The authors. Published by Alwaha Scientific Publishing Services SARL, ASPS. This is an open access article under the CC BY license.

1. Introduction

Municipal solid waste management is a major challenge in the rapidly growing mega cities of densely populated country like Bangladesh (Sohel et al., 2024). The generated waste in Dhaka City is mostly open dumped at landfills, but large portions of waste are not collected that widely impacts the public health, environment, social, and economic viability (Victoire et al., 2020). Municipal solid waste (MSW) continuously generates methane (CH₄) and other toxic gases which are 25 times stronger than carbon dioxide (CO₂) that are very harmful of public health (Mar et al., 2022).

In urban areas, waste management through WtE systems are not only reduce land pressure and GHGs emissions but also develop economy by producing heat and electricity (Islam, 2016). Waste-to-energy (WtE) conversion process is a sustainable solution of waste management, electricity generation and environmental protection (Islam, 2018). The WtE systems can reduce waste volume up to 90% through incineration, pyrolysis, gasification, anaerobic digestion and landfill gas to energy process (Kumar and Samadder, 2017). Based on MSW composition, developed countries mostly use INC technology but in developing countries AD technology is more appropriate (Alao et al. 2022). Despite some challenges, WtE systems can generate up to 27.40% of total global energy (Soni et al., 2025).

✉Corresponding author. E-mail address: abubakkarsiddique261@gmail.com

This work is licensed under a Creative Commons Attribution 4.0. License (CC BY 4.0) <http://creativecommons.org/licenses/by/4.0/>

ENERGY AND THERMOFLUIDS ENGINEERING | ETE | ISSN2716-8026 (PRINT)

Available online at <https://asps-journals.com/index.php/ete>

<https://doi.org/10.38208/ete.v6.1184>

Globally more than 800 MSW treatment plants treat approximately 400 million tons of MSW per annum and produce more than 430TWh of electricity (Sobamowo and Ojolo, 2018). In 2025, projected population in Dhaka city is 11.88 million that generates an average of 2.602 million tons MSW per annum where daily per capita waste generation ranges 0.60 to 0.72 kg (Akther et al. 2025). Recently, Islam et al. (2024) have been studied on dumped waste at Amin Bazar and Matuail landfills of Dhaka city and predicted that LFGTE technology will be economically profitable for per unit electricity price USD 0.21.

Though Bangladesh generates huge amount of renewable and non-renewable energy from different sources, but it is not enough to fulfil the energy demand of this fast-growing population. In Bangladesh, per capita energy consumption rate is 602 kWh/year, as a result every year at least 5% electricity is imported for fulfilling the demand (Chowdhury et al., 2025). Many researchers have reported that WtE techniques can make trustworthy possibilities for growing economic and social performance by creating jobs, business, public health and effective waste management (Ramos, 2024).

For profitable business, it is necessary to analyze life cycle cost (LCC) of a WtE system. LCC is an economic assessment tool that is used to assess all prospectives of initial and future comparative costs related to economic parameters (Medina-Salgado et al., 2021). The total lifespan costs like system installation, construction, land, operation and maintenance, fixed and variable costs of a project including decision making are assessed by applying LCC (Hemmati et al. 2024). The LCC tool helps to determine the total life span cost and economic assessment of waste management through WtE systems (Nubi et al., 2022).

Numerous studies have applied LCC methodology for cost-benefit analysis. (Sharma and Chandel, 2021) applied the LCC for different scenarios of waste management in India are recycling, composting, AD, INC with electricity generation, and landfill with biogas recovery and found the outcomes are the net LCC of per ton waste process with all combinations is USD 19 and only incineration USD 38. (Alidoosti et al. 2025) have been analyzed LCC for the scenarios of AD for heat and electricity, AD for household biogas, AD for fuel gas, pyrolysis for electricity, fermentation for bioethanol, and landfill gas collection for household use and the results reveal that landfill gas collection scenario is more profitable than other options. (Slorach et al., 2019) conducted a comparative study

involving LCC with the scenario's anaerobic digestion, in-vessel composting, incineration and landfilling in UK and assess the energy recovery potential and environmental impacts that incineration is better economic options but high carbon emissions technology. On the other hand, landfill gas to energy generation is more costly option for high LCC.

LCC and LCA has rarely been used in Bangladesh for economic and environmental impact assessment of waste management through WtE technologies. Joarder and Mamtaz (2025) are conducted a study on the scenarios of landfilling with composting; landfilling, composting, incineration; and landfill with incineration for economic and environmental impact assessment. The results reveal that 75% composting and 8.8% incineration of collected waste are environmentally most feasible options for land use and electricity generation for Dhaka city. By integrating LCC tool (Ashraf et al., 2024), analyzed the effective waste management and economic costs from decentralized waste-to-compost plant facility in Dhaka, Bangladesh and revealed that waste-to-compost plant is more economic and environment friendly options than landfilling.

However, limited study has been found on the comparative cost-benefit analysis and environmental impacts on carbon emissions of waste management through LFGTE, composting, AD, INC and GAS technologies in Dhaka city, Bangladesh, using LCC methodology. Waste management through WtE systems and LCC analysis can be significantly different depending on the limited studies in Dhaka city. Thus, the aim of this study is to evaluate the economic feasibility and carbon emissions on waste processing through AD, LFGTE, INC and GAS technologies in the perspective of Dhaka city using LCC analysis approach.

The objective of this study is to determine the optimal WtE technology which is economically feasible and environmentally acceptable options considering waste characteristics of Dhaka city.

The current analysis focuses on the subsequent research questions as follows:

- (i) Which WtE technology is more economic in the perspective of Dhaka city?
- (ii) Which cost parameters have more impacts on the WtE systems efficiency?
- (iii) Which WtE systems have more impacts on GHGs emissions in the perspective of Dhaka city?

2. Materials and Methods

2.1. Dhaka City

Bangladesh is an under-developed country with high population growth rate as in other developing countries. Within 1,47,570 square kilometer area of Bangladesh, population is about 169.83 million where urban and rural population ratios are 31.66% and 68.34%, respectively (Manik, 2024). Dhaka city contains total area 305 square kilometers. The geographic position of Dhaka city is 23°53' and 24°06' north latitudes and 90°01' and 90°37' east longitudes. In this study, we have considered the raw data and projected data for Dhaka city corporation area rather than Dhaka metropolitan area.

The LCC results of WtE systems in urban perspective could potentially change for the factors such as geographic position, governance, economic development and social status of the population. Life cycle costs (LCC) analysis of WtE conversion processes is important for Dhaka city because the city faces continuous challenges such as growing population and generated waste and increasing demand of electricity. Dhaka city produces 69.7% of the total waste stream of other cities of Bangladesh (Islam, 2018). The waste composition of Dhaka city is shown in **Figure 1**, where major portions of waste is organic for geographic conditions (Islam, 2016 and Shams et al., 2017).

Dhaka is a centre of all administrative and commercial activities of Bangladesh. It is most populous city of the country where projected population in 2025 is approximately 11.88 million and 39,000 citizens living per square kilometers (Akther et al. 2025). In different municipalities of Bangladesh daily per capita MSW generation rate was 0.2 to 0.56 kg as 2012 (Ahsan et al., 2014). In 2025, Dhaka city daily generates more than 7500 tons of MSW where daily per capita waste generation rate

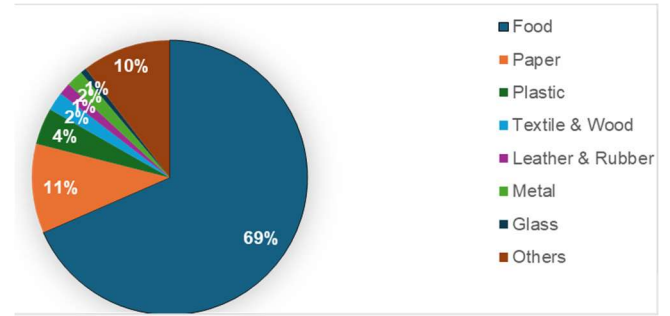


Figure 1. Waste composition of Dhaka city (Islam, 2016)

is 0.60 kg. It is expected to be 8500 tons/day by 2032 and 12000 tons/day by 2050 (Akther et al., 2025). The city authorities are trying to manage this vast amount of waste, but they are unable to manage effectively (Samiul Islam, 2023) because on average 57% of total generated waste are collected through different sources (Akther et al. 2025). In Dhaka city, there are many limitations of waste management such as low resources or budget allocation, lack of technical advancement and lack of coordination among public-private partnership in waste management (Jerin et al., 2022).

2.2. Waste-to-energy systems and by-products

The outcomes of waste processing through WtE systems are biogas, bio-oil, syngas and agricultural fertilizer. WtE systems has some merits and demerits based on waste characteristics, processing costs and economic profits. Thermo-chemical technologies are incineration technology produces heat from combustible waste, GSF technology produces syngas, pyrolysis technology produces bio-oil, syngas and charcoal from MSW (Hernández-Romero et al., 2024) and Bio-chemical technologies are AD technology produces biogas and fertilizer from organic or food waste and LFGTE technology produces landfill gas that's shown in **Figure 2** (Beyene et al., 2018).

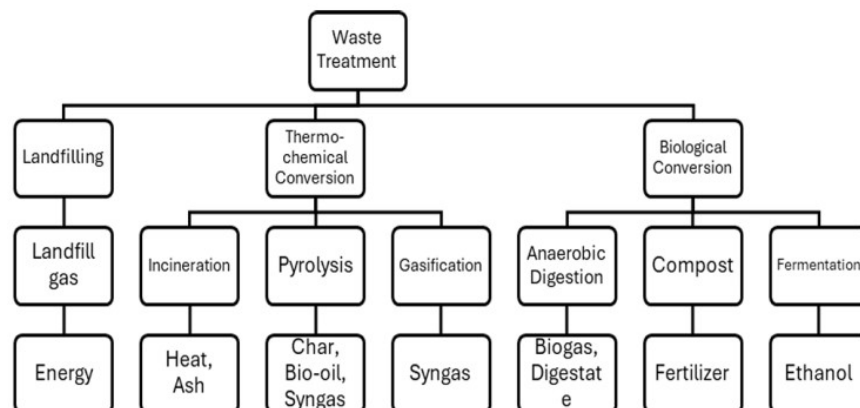


Figure 2. WtE and by-products

2.3. Life cycle costs (LCC)

According to International Standard Organization code 14040 and 14044 for LCC approach, we follow the methodological steps such as (a) Goal and Scope, (b) Inventory Analysis, (c) Impact Assessment, and (d) Interpretation.

2.3.1 Goal and Scope of LCC analysis

This study aims to evaluate the economic feasibility and environmental impacts of different WtE technologies for implementing WtE systems in Dhaka city. The functional unit is taken as 1 ton of processed MSW in each of the four technologies for economic assessment.

2.3.2 Inventory Analysis

This study is conducted in Dhaka city on the scenario of population growth, waste management, waste generation, waste composition, characteristics of MSW and disposal data from 2010 to 2026 are collected from the relevant literature reviews. From this, a projection of the future population and MSW generation in Dhaka city over a period of 20 years (2028-2048) is made. Cost related data for the WtE systems are collected from relevant literature that are used in different countries because no specific data are available for Bangladesh. According to Bangladesh energy regulatory commissions, residential electricity unit price rate ranges between BDT 4.63 to 14.61/kWh but in business, industry and construction sector electricity unit price rate between BDT 12.40 to BDT 20.17/kWh and some extra charges added with electricity price in the year 2024. Electricity unit price rate always changes with the user demand, economic development and rate of inflation. Bangladesh electricity regulatory commissions increase electricity unit price up to 20% on previous price rate in June, 2026. For this reason, in this study we assumed electricity price BDT 18/kWh for economic feasibility analysis. Since electricity unit price continuously increases with the rate of inflation. In this study, electricity unit price is considering BDT 18/kWh however, USD 1 equivalent to BDT 122 according to February, 2026.

3. Mathematical Formulations

3.1 Projected Population and MSW Generation

The future forecasted population is calculated by regression analysis based on the raw data found from population census data of Bangladesh Bureau of Statistics

(BBS) in the year 1991, 2001, 2011 and 2022 for Dhaka city of Bangladesh shown in **Table 1**.

The regression line (1) is found by using raw data of **Table 1** and the projected population can be found from equation (1). The populations of Dhaka city are not continuously rising for all points according to raw and projected data shown in **Figure 3**.

Table 1. The population raw data of Dhaka city according to BBS census (Manik, 2024).

Year	Dhaka North City (Pop. in million)	Dhaka South City (Pop. in million)	Total population (in millions)
1991	-	-	4.174
1992	-	-	4.362
1993	-	-	4.558
1994	-	-	4.763
1995	-	-	4.978
1996	-	-	5.202
1997	-	-	5.436
1998	-	-	5.680
1999	-	-	5.936
2000	-	-	6.203
2001	-	-	6.483
2002	-	-	6.692
2003	-	-	6.909
2004	-	-	7.132
2005	-	-	7.362
2006	-	-	7.599
2007	-	-	7.845
2008	-	-	8.099
2009	-	-	8.360
2010	-	-	8.630
2011	4.920	3.990	8.910
2012	5.009	4.014	9.023
2013	5.099	4.042	9.142
2014	5.191	4.071	9.262
2015	5.285	4.099	9.385
2016	5.381	4.128	9.509
2017	5.478	4.157	9.635
2018	5.577	4.186	9.763
2019	5.678	4.216	9.893
2020	5.780	4.245	10.026
2021	5.885	4.275	10.160
2022	5.991	4.305	10.296

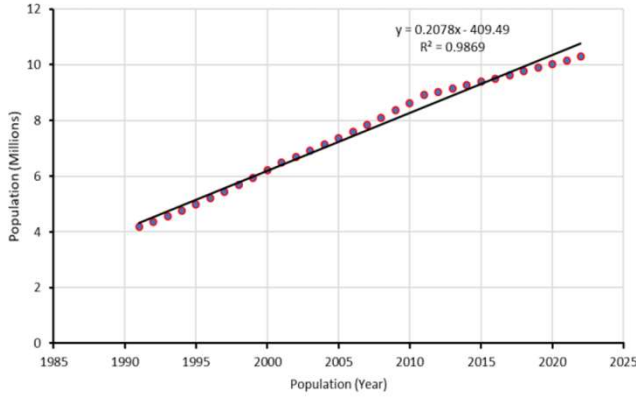


Figure 3. Raw data and projected data with respect to standard fitting line.

The projected population regression line is:

$$y = mx + c \quad (1)$$

where y is projected population, m is the slope of the regression line = 0.20801686, x is population year and c is y -intercept = -409.8403 (calculated).

The projected waste generation of Dhaka city can be calculated by two method such as historical trend and compound annual growth rate approach (Islam, 2016) which are shown in equations (2a) and (2b).

(i) Historical trend: the annual population growth rate in the respective city was computed from census data, and the average growth rate in the per capita waste generation was computed from historical waste generation (2028 to 2048).

$$W = P \times (W_b + W_b \times W_{agr}) \times 0.365 \quad (2a)$$

Here, W = Projected waste generation in a year (tons), P = Projected population in each year (millions), W_b = Per capita waste generation in the baseline year (kg/cap/day), W_{agr} = Average growth rate of per capita waste generation.

(ii) Compound annual growth rate, gross annual product, and income spending approach. The compound annual growth rate of the respective city population is first calculated using census data. Gross yearly product growth rate of Bangladesh is assumed 4% and 70% of income is supposed to be used for expenditure to bear the personal consumption in Bangladesh. The waste generation growth factor is calculated as 0.028 (4% × 70%).

Projected waste generation was calculated using,

$$W = P \times (W_b + W_b \times W_{gf}) \times 0.365 \quad (2b)$$

Here, W = Projected wastes generation in a year (tons), P = Projected population in each year, W_b = Per capita wastes generation in the baseline year (kg/cap/day), W_{gf} = Waste generation growth factor.

The amount of collected waste is:

$$W_c = W_g \times D_f \quad (3)$$

where W_g is average projected waste generation and D_f is fraction of collected waste and it is assumed to be 50% for Dhaka city. The technology-based demand of waste composition is determined by following equation (Ogunjuyigbe et al., 2017):

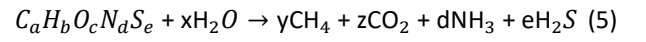
$$W_f = W_c \times f \quad (4)$$

where f is technology wise used waste composition.

3.2 Determination of Electricity Generation Potential of WtE Systems

3.2.1 Anaerobic Digestion (AD)

To determine the electricity generating potential of biogas, it is necessary to find out the amount of methane (m^3 /ton) in MSW feedstock. The modified Buswell and Mueller equation is used to determine the maximum theoretical methane production from the complete degradation of the MSW feedstock (Nielfa et al., 2015). The equation is



$$x = a - \frac{b}{4} - \frac{c}{2} + \frac{3d}{4} + \frac{e}{2} \quad (5a)$$

$$y = \frac{a}{2} + \frac{b}{8} - \frac{c}{4} - \frac{3d}{8} - \frac{e}{4} \quad (5b)$$

$$z = \frac{a}{2} - \frac{b}{8} + \frac{c}{4} + \frac{3d}{8} + \frac{e}{4} \quad (5c)$$

where a , b , c , d , e are representing the carbon, hydrogen, oxygen, nitrogen and sulfur moles, respectively. The moles a , b , c , d and e can be determined by the following mole ratio relation given by (Salami et al., 2011). The relation is

$$Moleratio = \frac{K[C,H,O,N]}{M[C,H,O,N]} \quad (6)$$

where K is the element composition in MSW and M is element molar mass that shown in **Table 3**. In this study assumed, 50% of collected waste is processed for AD technology.

Table 2. Raw data to determine the projected MSW in Dhaka city (Akther et al., 2025)

Base waste generation rate (W_b) (kg/cap/day)	D_f (%)	Lifetime (years)
0.65	50.00	20.00

Table 3. Element composition of MSW generated in Dhaka city (Islam, 2018)

Waste type	C %	H %	O %	N %	S %	Ash %	Moist %
Food	48	6.4	37	0.4	2.6	5	72.34
Wood/Yard	47.8	6	38	0.3	3.4	4.5	38.2
Plastic	60	22.8	7.2	0.1	0	10	0.53
Paper	43.5	6	44	0.2	0.3	6	3.2
T/R/L	55	6.6	31	0.1	90	2.5	0

*T/R/L = Textile/Rubber/Leather

The mass of methane (Kg) is calculated by

$$M_{CH_4} = \frac{16 \times y \times 100}{(M_C \times a) + (M_H \times b) + (M_O \times c) + M_N} \quad (7)$$

where y is CH₄ composition that can be calculated by using equations (5b) and (6).

The volume of the methane can be found from the following relation (Ayodele et al., 2018),

$$V_{CH_4} = M_{CH_4} \div \rho_{CH_4} \quad (8)$$

$\rho_{CH_4} = 0.667 \text{ Kg/m}^3$ = Density of methane. The theoretical methane is always greater than actual methane production (Ayodele et al., 2018) and it is assumed to be 85%.

So, actual volume of methane is

$$V_{CH_4(Actual)} = 85\% \times V_{CH_4} \quad (9)$$

Hence generated electricity (kWh/ ton) from anaerobic digestion (AD) is

$$E_{AD} = V_{CH_4(Actual)} \times LHV_{CH_4} \times CF \times \eta \div C_0 \quad (10)$$

According to (Chowdhury, 2021; Mostakim et al., 2021) LHV_{CH₄} is lower heating value of methane = 37.2 MJ/m³, η is energy conversion efficiency = 26%, CF is capacity factor = 85% and MJ to kWh is conversion factor, $C_0 = 3.6$.

3.2.2 Landfill Gas to Electricity (LFGTE)

Electricity generating efficiency of LFGTE technology depend on the amount of methane captured from landfill processed waste. The methane potential (kg/ton) of waste can be found by (Islam, 2018),

$$CH_4 = W_T \times W_F \times MCF \times DOC \times DOC_F \times (16/12 - R) \cdot (1 - O_x) \cdot F \quad (11)$$

where MCF is methane correction factor = 0.60 for uncategorized waste, W_T is total organic waste = 970 kg per ton for Dhaka city, W_F is generated MSW disposed at landfill is 100%, DOC_F is the fraction of degradable organic carbon = 77%, F is volume fraction of CH₄ = 50%, R is Recovered methane = 0 and O_x is Oxidation factor = 0 (Islam, 2018).

Degradable organic carbon (DOC) is found by

$$DOC = 0.4p + 0.17q + 0.15r + 0.3s \quad (12)$$

where p, q, r and s are represents the fraction of paper, garden, food and wood waste, respectively.

Electricity (kWh/ ton) generated by LFGTE technology is,

$$E_{LFGTE} = V_{CH_4} \times LHV_{CH_4} \times \lambda \times CF \times \eta \div C_0 \quad (13)$$

According to the researchers (Mayilsankar et al., 2026), V_{CH_4} is volume of landfill gas; λ is methane capture efficiency = 75%; η is energy conversion efficiency of internal combustion engine = 38%; CF is capacity factor = 90% and C_0 is conversion factor from MJ to kWh = 3.6.

3.2.3. Incineration (INC)

The amount of electricity generated from heat turbines can be found by (Escamilla-García et al., 2020):

$$E_{INC} = M \times LCV \times CF \times \eta_{INC} \div C_0 \quad (14)$$

where M is mass of waste; LCV is lower calorific value of combustible waste; η_{inc} is energy conversion efficiency = 25%; CF is capacity factor of the system = 0.8. LCV is found by (Escamilla-García et al., 2020),

$$LCV = \{40(p + q + r + s) + 90t - 46W\} \div K_0 \quad (15)$$

where p, q, r, s and t are the percentage of paper, textile, wood, food, plastics and rubber waste composition respectively content in MSW. For MSW incineration technology, water or moisture (W) is removed during preheating of MSW hence consider $W = 0$ and $K_0 = 238.86$ represents kCal/Kg to MJ/Kg data shown in **Table 3**.

3.2.4 Gasification (GAS)

The amount of electricity generated from gasification technology that can be calculated by (Alzate et al., 2019):

$$E_{GAS} = M \times R_f \times LCV \times \eta_{GAS} \div C_0 \quad (16)$$

where M is mass of MSW (tons), R_f is waste rejection after the mechanical treatment is taken as 72.5%; LCV is determined from equation (15) when average waste moisture consider 38% data from **Table 3** and $\eta_{(GAS)}$ is the system efficiency 23% (Fernández-González et al., 2017).

3.3 Determination of Cost of the WtE systems

3.3.1 Anaerobic Digestion (AD)

The installation cost of AD is calculated by,

$$Capex = C_p \times P_s \quad (17)$$

$$Opex = 0.03 \times Capex + 0.005 \times E_{INC} \quad (18)$$

where C_P is plant cost USD 4339/kW; Opex is sum of 3% of Capex and 0.5% of generated electricity (USD) and P_s is plant capacity in KW (Chowdhury, 2021).

3.3.2 Landfill Gas to Energy (LFGTE)

The installation cost of LFGTE is calculated by,

$$Capex = C_1 + C_2 + C_3 + C_4 + C_5 \quad (19)$$

where C_1 , C_2 , C_3 , C_4 and C_5 are the costs of vertical gas extraction wells, wellheads (and pipes gathering), knockout (blower and flare), engineering (permitting and surveying) and internal combustion engine respectively. These are calculated by following equations (20-24):

$$C_1 = (h - 10) \times 85 \times N \quad (20)$$

$$C_2 = 17000 \times N \quad (21)$$

$$C_3 = 4600 \times v^{0.6} \quad (22)$$

$$C_4 = 700 \times N \quad (23)$$

$$C_5 = 1300 \times P_s + 1100000 \quad (24)$$

where h is well depth = 65 feet, v is methane flow rate = 61.5 m³/ton, N is the number of wells = 50 and P_s is plant size (Ayodele et al., 2018).

Opex of LFGTE is calculated by (Ayodele et al., 2018),

$$Opex = Opex_1 + Opex_2 \quad (25)$$

$$Opex_1 = 2600 \times N + 5100 \quad (26)$$

$$Opex_2 = 0.025 \times E_{LFGTE} \quad (27)$$

where $Opex_1$ is landfilling cost and $Opex_2$ is internal combustion engine cost = 2.5% of generated electricity.

3.3.3 Incineration (INC)

Capital expenditure (Capex) and operational expenditure (Opex) can be calculated by (Escamilla-García et al., 2020),

$$Capex = 15797 \times P_s^{0.82} \quad (28)$$

$$Opex = 0.04 \times Capex \quad (29)$$

where P_s means plant capacity in KW.

3.3.4 Gasification (GAS)

To produce high energy content syngas and process vast amount of waste Bubbling Fluidized Bed (BFB), GSF technology has better performance than another gasifier.

Capital expenditure (Capex) and operational expenditure (Opex) can be calculated by,

$$Capex = 3925 \times P_s \quad (30)$$

$$Opex = 0.04 \times Capex + 0.004 \times E_{GAS} \quad (31)$$

where P_s is plant capacity (Mabalane et al., 2021).

Again, plant capacity or size (KW) can be calculated by the following relation

$$P_s = E_i \div 8760 \quad (32)$$

where E_i is generated electricity through each technology and 1 year = 365 days = 8760 hours.

3.4 Economic Assessment of WtE systems

To determine the economic performance of WtE systems, it is necessary to estimate the value of economic indicators such as project life cycle cost (LCC), levelized cost of energy (LCOE), net present value (NPV), internal rate of return (IRR) and payback period (PBP).

3.4.1 Life Cycle Cost (LCC)

LCC refers to total capital and operational expenditure costs in the effective lifetime of the plant. It can be calculated by following way (Nubi et al., 2022),

$$LCC = Capex + \sum_{t=1}^n \frac{Opex}{(1+\alpha)^t} \quad (33)$$

Here α is considered 10% discount rate for this study.

3.4.2 Levelized Cost of Energy (LCOE)

LCOE means minimum cost per unit energy generation cost of a system to generate electricity when it breaks even (Ayodele et al., 2018). The least selling price of electricity per unit can be found from LCOE value. It is found by (34-35),

$$LCOE = \frac{LCC}{E_P} \times CRF \quad (34)$$

Capital Recovery Factor,

$$CRF = \frac{\alpha(1+\alpha)^n}{(1+\alpha)^n - 1} \quad (35)$$

α is discount rate taken as 10%.

3.4.3 Net Present Value (NPV)

Net present value mean net cash flow that can be found by deducting net cost (capex and opex) from net revenue earned over whole lifetime of the system (Chowdhury, 2021). NPV can be calculated by the equation (36),

$$NPV = \sum_{t=0}^n \frac{P_t}{(1+\alpha)^t} = P_0 + \frac{P_1}{(1+\alpha)^1} + \dots + \frac{P_n}{(1+\alpha)^n} \quad (36)$$

where P_t is net cash flow or profit; t is project life time 20 years and P_0 is installation cost (Ayodele et al., 2018).

Cash flow of a company states the difference between total revenue and total expenditures in each year. The net cash flow P_n can be found by equation (37),

$$P_t = Rev - (Capex + Opex) \quad (37)$$

where Rev means revenue from WtE systems.

The revenue of energy generating industry (Fernández-González et al., 2017) can be found by equation (38),

$$Rev = E \times S_p \quad (38)$$

where E is the amount of electricity that comes from specific technology and S_p is the per kWh electricity price. In this study electricity unit price consider BDT 18/kWh.

3.4.4 Internal Rate of Return (IRR)

IRR is such financial parameter which converts net present value (NPV) or sum of all future cash inflows equal to zero or very small positive unit. It is used to determine the profitability of certain amount of investment. IRR has the highest discount rate at which the project still breaks even (Islam et al., 2024). It can be calculated by equation (39),

$$NPV = -P_0 + \sum_{t=1}^n \frac{P_t}{(1+IRR)^t} = 0 \quad (39)$$

where P_0 is investment cost and P_t is per year benefit.

3.4.5 Payback Period (PBP)

Payback Period is the time bound of a system which comes to profit by recovering its capital and operational expenditures (Pheakdey et al., 2023). It can be calculated by

$$PBP = \frac{Capex}{Rev - Opex} \quad (40)$$

3.5 Environmental Assessment of WtE systems

3.5.1 Global warming potential of Open Landfilling

Despite interest in WtE technology, generally dispose MSW in the landfill without sorting, treating and energy recovery practice. The emissions of decomposed organic waste produce methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S) and toxic gases that are responsible for environmental pollution. Methane generated in the open landfill (OLFG) ²is directly 90% emitted to the atmosphere and the remaining 10% is converted to carbon dioxide by oxidized. The methane emission for the untreated waste is calculated by (Ayodele et al., 2017):

$$GWP_{OLFG} = 0.9 \times OLFG_{CH_4} \times GWP_{CH_4} \quad (41a)$$

3.5.2 Global warming potential of LFGTE technology

The methane collection efficiency from landfill is 75% and 25% of methane is released into the atmosphere after capturing that leading to global warming (Ayodele et al., 2017). The global warming potential LFGTE can be found by,

$$GWP_{LFGTE} = LFGTE_{CH_4} \times GWP_{CH_4} \times 0.25 \quad (41b)$$

where GWP_{CH_4} is equivalent to 25 kg CO_2 and per ton waste generate methane gas through LFGTE_{CH4} technology is 47.6 kg.

The dioxin/furans are found by the following equation,

$$E_{(dioxin)LFGTE} = SE_{(p)} \times E_{P(LFGTE)} \quad (41c)$$

where $SE_{(dioxin)}$ is specific emission factor (1.4946×10^{-9} kg/MWh) and $E_{P(LFGTE)}$ is electricity (MWh) generated from LFGTE technology (Ayodele et al., 2017).

3.5.3 Global warming potential of AD technology

The anaerobic digestion (AD) process produces biogas and agricultural fertilizer. In case of AD technology, 5% of produced methane is leaked into atmosphere which is responsible for GHG (such as CO_2) emissions (Huang and Fooladi, 2021). The global warming potential (kg CO_2 eq.) AD can be found by,

$$GWP_{AD} = 0.05 \times AD_{CH_4} \times GWP_{CH_4} \times 0.717 \quad (42)$$

where GWP_{CH_4} is equivalent to 25 kg CO_2 and AD_{CH_4} is 238.4 kg/ton.

Generated NH_3 and H_2S during anaerobic digestion are calculated by,

$$\begin{aligned} NH_3 &= \text{Nitrogen from per ton MSW} \times \text{Mass of } NH_3 \\ &= 0.2 \times 17 = 3.4 \end{aligned} \quad (43a)$$

$$\begin{aligned} H_2S &= \text{Sulphur from per ton MSW} \times \text{Mass of } H_2S \\ &= 0.55 \times 34 = 18.7 \end{aligned} \quad (43b)$$

Assuming 5% of generated NH_3 and H_2S are leaked into atmosphere as NO_x and SO_x whose are responsible for emissions and environmental pollutions (Richard et al. 2022).

$$NH_3 = 0.05 \times 3.4 = 0.17 \text{ kg/t emitted as } NO_x \quad (44a)$$

$$H_2S = 0.05 \times 18.7 = 0.935 \text{ kg/t emitted as } SO_x \quad (44b)$$

3.5.4 Global warming potential of INC technology

The combustible waste portions of Dhaka city are approximately 87% which includes food, paper, textile & rubber, wood, and plastics. The high moisture content

waste can be used in the combustion process after drying the waste volume. The biogenic and fossil carbon dioxide are emitted as 67% and 33%, respectively during incineration process (Guendehou et al., 2006). The carbon dioxide emissions from incineration technology are calculated by,

$$\text{CO}_2 \text{ Emissions} = \sum \text{MSW}_{F(i)} \times C_i \times O_F \times 44/12 \quad (45)$$

where $\text{MSW}_{F(i)}$ refers to the combustible portions of MSW, C_i is the carbon content of each combustible portion, and O_F is oxidation factor consider 1 and 44/12 is the carbon content of CO_2 (Guendehou et al., 2006). The emissions of CO , N_2O , NH_3 and NO_x are calculated by using emission factors as given by (Guendehou et al., 2006):

$$\text{Nox Emissions} = 200\text{mg}/\text{m}^3 \times 5500 \text{ m}^3/\text{t} \times \text{MSW}_F = 0.957\text{kg}/\text{t}$$

$$\text{N}_2\text{O Emissions} = 2\text{mg}/\text{m}^3 \times 5500\text{m}^3/\text{t} \times \text{MSW}_F = 0.00957 \text{ kg}/\text{t}$$

$$\text{CO Emissions} = 50\text{mg}/\text{m}^3 \times 5500 \text{ m}^3/\text{t} \times \text{MSW}_F = 0.2395 \text{ kg}/\text{t}$$

$$\text{NH}_3 \text{ Emissions} = 4\text{mg}/\text{m}^3 \times 5500 \text{ m}^3/\text{t} \times \text{MSW}_F = 0.0191 \text{ kg}/\text{t}$$

3.5.4.1 Acidification Potential of INC technology

Waste processing through incineration technology are emitted several gases like SO_2 , NO_x , HF, HCl and H_2S into the atmosphere. Some toxic gases (SO_2 and HCl) are responsible for acid rain (Cudjoe and Han, 2020). The emissions of acidification potential is found by the product of acid gases (HCl and SO_2):

$$E_{\text{INC}(ap)} = E_{\text{SO}_2} \times E_{\text{HCl}} \quad (46)$$

where the released sulfur dioxide and hydrogen chloride emissions into atmosphere can be determine by following:

$$E_{\text{SO}_2} = SE_{\text{SO}_2} \times MWS_{\text{comb}} \times EF_{\text{SO}_2} \quad (46a)$$

$$E_{\text{HCl}} = SE_{\text{HCl}} \times MWS_{\text{comb}} \times EF_{\text{HCl}} \quad (46b)$$

where the emission release factors SE_{SO_2} and SE_{HCl} are given as 0.277 and 0.106 kg/tons, respectively ((Cudjoe and Han, 2020). On the other hand, EF_{SO_2} and EF_{HCl} are the emission equivalent factors given as 1.0 and 0.88 kgSO_2 , respectively (Silva et al., 2020).

3.5.4.2 Dioxin Potential of INC technology

The dioxins known as polychlorinated dibenzo-p-dioxins and dibenzofurans. In case of incineration process, unburned waste residues generate dioxins or furans that is alarming for public health (Ayodele et al., 2017; Yao et al., 2019). The dioxin emissions from INC can be calculated as follows:

$$E_{\text{INC}(dioxin)} = SEF_{\text{INC}(dioxin)} \times MWS_{\text{comb}} \quad (47)$$

where $SEF_{\text{INC}(dioxin)}$ is the specific emission factor of the INC are taken as 3.31×10^{-8} kg/tons (Ayodele et al., 2017).

3.5.5 Global warming potential of GAS technology

The emissions of GAS technology are calculated by (Nubi et al. 2022) using the following equation (48),

$$\text{Emission (kg/ton)} = \sum \text{MSW}_i \times \text{EF} \quad (48)$$

where MSW_i is amount of waste (ton) and EF is emission factors.

Air emissions factors of GAS technology are:

$\text{NO}_x = 78\%$; $\text{SO}_x = 5.2\%$; $\text{HCl} = 3.2\%$; CO_2 (biogenic) = 60.5%; CO_2 (fossil) = 39.5%; $\text{Hg} = 0.0069\%$; $\text{Ar} = 0.006\%$;

$\text{Ni} = 0.004\%$; $\text{Cd} = 0.00069\%$; $\text{VOC} = 1.1\%$; $\text{HF} = 0.034\%$.

So, fossil CO_2 emissions rate is found $0.395 \times 870 \text{ kg}/\text{ton} = 343.65 \text{ kg}/\text{ton}$ since 87% is gasifiable waste of entire MSW composition.

Water emissions factors of GAS technology are:

$\text{Al} = 18\%$; $\text{Fe} = 9.7\%$; $\text{Cl} = 4.8\%$

3.6 Interpretation

The LCC results interpretation of this study are economic costs, cash flows from net revenues, performance of the WtE systems, and limitations. The economic analysis of LCC methodology is conducted on the variation of the parameters such as capital costs, electricity price, population, and waste growth rate etc. Again, the environmental analysis is conducted based on carbon dioxide and other toxic gas emissions.

4. Results

4.1 Economic Results Analysis

The projected population and waste generation in 20-year spanning from 2028 to 2048 for Dhaka city is shown in **Figure 4** and results demonstrate that the amount of waste in Dhaka city is continuously rising with population growth rate. In 2028, projected population is 12.018 million where projected waste generation is 2.931 million tons/year. The population and waste generation in the mega cities like Dhaka are continuously increases for urbanization, industrialization and economic development. After 20 years, projected population and waste generation

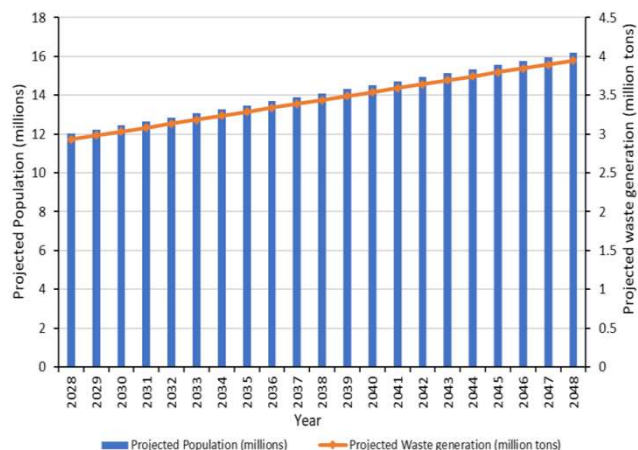


Figure 4. Population vs waste generation scenario of Dhaka city

will rise more than 1.35 times higher. In Dhaka city, energy generation efficiency of AD, LFGTE, INC and GAS technologies are 721.35 kWh/ton, 176 kWh/ton, 599.33 kWh/ton and 330.44 kWh/ton, respectively. AD has highest electricity generation potential because major portion of waste in Dhaka city are organic waste where 68.3% is food waste in the total waste streams. Again, LFGTE has the lowest electricity generation potential and approximately 75% of captured methane can be used for electricity and household purpose and 25% is emits as GHGs into environment. Electricity generating potential of INC and GSF technologies depend on waste calorific value that is comparatively better than LFGTE technology.

This study assesses the economic viability and performance of WtE systems from the outcomes of the economic indicators are shown in **Table 4**; showing that INC has lowest LCC value BDT 22914/ton and AD have highest LCC value BDT 56,065/ton but LFGTE and GAS have moderate LCC value for per ton waste processing costs. LFGTE technology have highest LCOE value BDT 20.72/kWh and INC technology have lowest LCOE value BDT 4.49/kWh but for AD and GAS have moderate LCOE value BDT 9.13 and 8.87/kWh, respectively. The LCOE outcomes represents that all WtE systems are feasible except LFGTE technology and INC is more economic among the technologies. The results of NPV for all WtE systems are positive except LFGTE technology and for INC technology it is highest among the technologies. So, LFGTE is not economically feasible in Dhaka city. It can be possible if initial investment cost is lower than the future revenue generated. From **Table 4**, INC has the highest NPV value but AD and GAS have moderate NPV.

Table 4. Economic performance of WtE systems in Dhaka city (For base electricity price BDT 18/kWh).

Economic parameters	AD	LFGTE	INC	GAS
LCC (BDT/ton)	56,065	31,049	22,914	24,949
LCOE (BDT/kWh)	9.13	20.72	4.49	8.87
NPV (BDT/ton)	55,788	-3,531	69,593	26,412
IRR (%)	27	8	61	29
PBP (Years)	3.73	9.86	1.64	3.46

Figure 5 to Figure 8 show that LCC and LCOE continuously increases and NPV decreases if Capex increases and vice-versa for all technologies. The results shows that LCC is higher for AD technology and lower for INC technology. For LFGTE technology, NPV is negative. If Capex decrease more than 15% from actual Capex, then NPV of LFGTE technology will be positive. On the other hand, NPV of INC technology is positive and higher among the technologies.

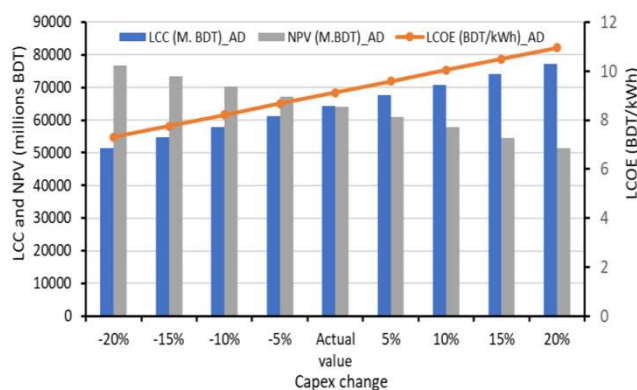


Figure 5. Effect of Capex on LCC, LCOE and NPV

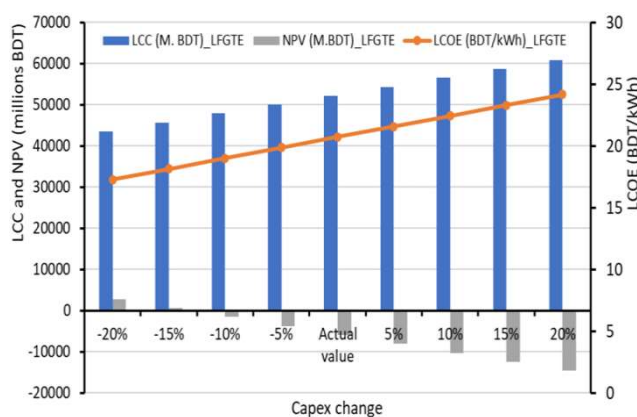


Figure 6. Effect of Capex on LCC, LCOE and NPV

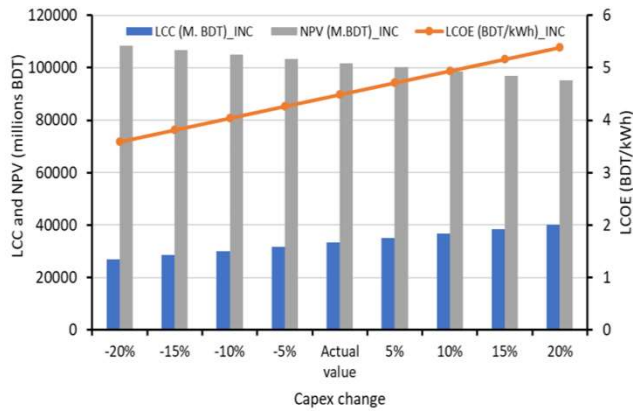


Figure 7. Effect of Capex on LCC, LCOE and NPV

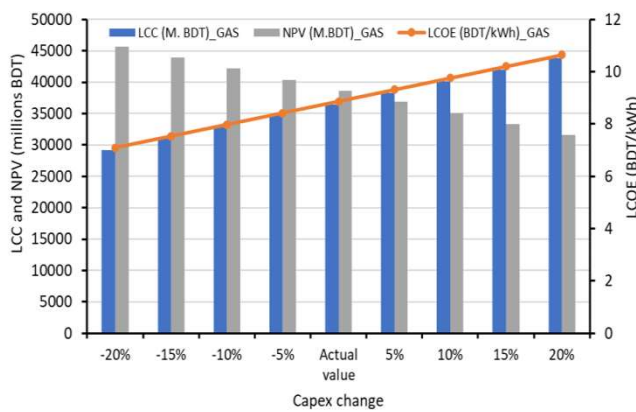


Figure 8. Effect of Capex on LCC, LCOE and NPV

Figure 9 shows that NPV increases with the continuous increase of electricity price for all technology where NPV of LFGTE technology is lower than other technologies. Figure 9 also shows that LFGTE technology will be economic if electricity price is greater than BDT 20.72/kWh then NPV of LFGTE technology will be positive.

From Figure 10 shows that all WtE systems are viable and feasible except LFGTE technology because IRR value is less than considered discount rate. INC has the highest IRR (61%), followed by GAS (29%) and AD with an IRR (27%) for electricity price BDT 18/kWh. If electricity price BDT 8/kWh, then IRR are 8, -4, 25 and 9% for AD, LFGTE, INC and GAS technologies, respectively. Again, if electricity price BDT 24/kWh, then then IRR are 37, 13, 83 and 40% for AD, LFGTE, INC and GAS technologies, respectively. Figure 10 also shows that IRR increases with the continuous increase of electricity unit price for all technology but in case of INC technology, IRR value is higher among the technology.

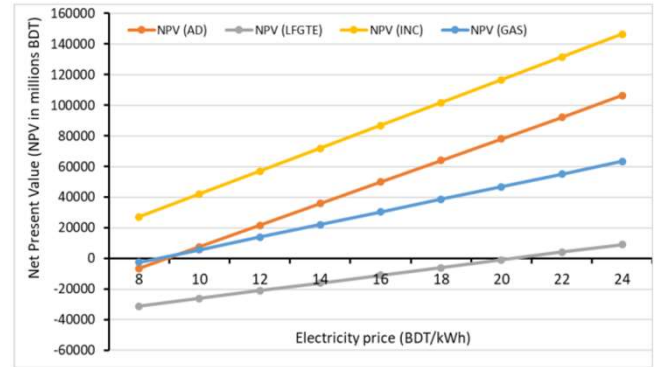


Figure 9. Effect of Electricity price on NPV

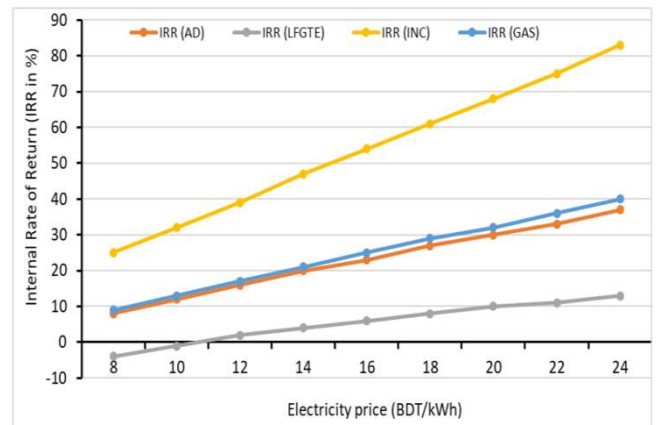


Figure 10. Effect of Electricity price on IRR

Figure 11 shows that PBP decreases with the continuous increase of electricity unit price for all technology but in case of INC technology, PBP value is always lower among the technology. For electricity unit price BDT 8/kWh, PBP are 9.77, 30.01, 4.02 and 9.41 years for AD, LFGTE, INC and GAS technologies, respectively. Again, for electricity price BDT 24/kWh, PBP are 2.72, 7.03, 1.21 and 2.51 years for AD, LFGTE, INC and GAS technologies, respectively.

Therefore, overall outcomes indicate that INC technology is economically most feasible options and LFGTE technology is economically least favorable option.

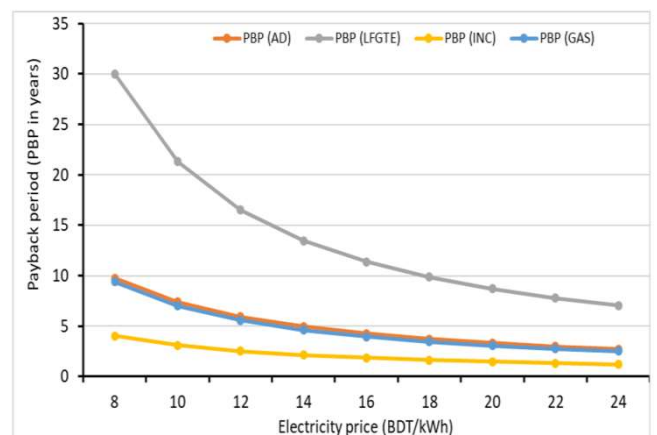


Figure 11. Effect of Electricity price on PBP

4.2 Environmental Results Analysis

The biodegradable waste emits greenhouse gas (GHG) or carbon dioxide and other toxic gases. The waste landfills are generating higher emissions than engineered landfills and other technological process whose are responsible for environmental pollution. The rate of CO₂ emissions from LFGTE, AD, INC and GAS technologies are 297.5, 213.7, 508 and 343.6 kgCO₂ eq for per ton waste, respectively. **Figure 12** shows that without capturing methane gas, the landfills (open dumping) emit 1071 kg CO₂ eq./ton waste much higher compared to engineered landfills (LFGTE technology). methane (LFGTE technology) capturing emits much lower that is 297.5 kg CO₂ eq./ton waste. LFGTE technology with energy recovery more environment freindly options than landfilling. **Figure 13** reveals that the GHGs emissions of INC technology is higher and for AD technology it is lower among the technologies. In the year 2028, AD, LFGTE, INC and GAS technologies emits 213, 425, 648 and 504 kton CO₂ eq, respectively. This emission increases with respect to waste processing rate. In 2048, the amount of emissions rises at 288, 575, 872 and 678 kton CO₂ eq, respectively. The effect of global warming potential (GWP) for same amount of MSW is processed by WtE systems are shown in **Figure 14** reveals that AD emits lower GHGs emissions and INC emits higher GHGs emissions but LFGTE and GAS emits moderate amount of GHG emissions. For all technologies, GHG emissions gradually increases with the increase of waste processing rate. INC technology has higher energy generation efficiency with higher carbon emissions rates among the technologies. On the other hand, gasification technology has moderate GHG emissions and energy generation efficiency technologies. Anaerobic digestion technology has higher energy generation efficiency and lower GHG emissions.

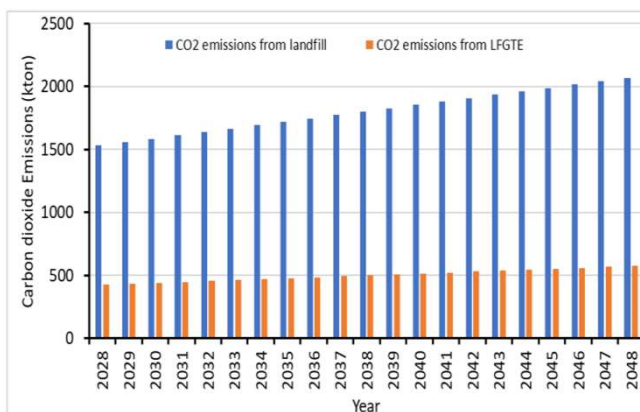


Figure 12. Comparison of CO₂ Emissions with landfilling and LFGTE technology

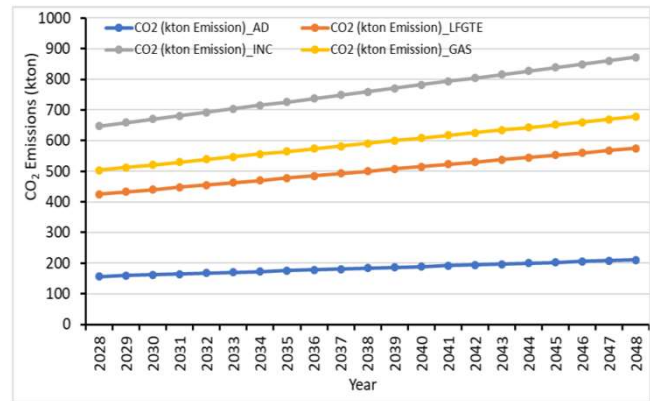


Figure 13. Amount of CO₂ Emissions per year

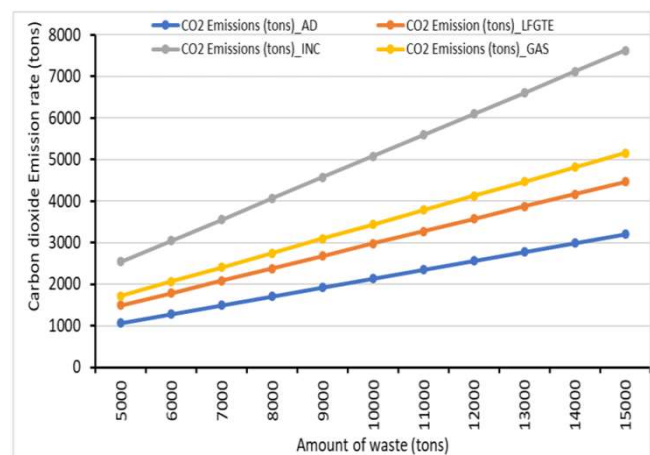


Figure 14. Comparative potential global warming rates of WtE systems

Figure 15 depicts that the acidification potential of INC technology which is causing acidic rain by chemical reactions of sulfur dioxide and hydrogen chloride gas. The emissions are expected to range 42 kttons to 76 kttons SO₂ eq. over project lifespan (2028 to 2048) and it is depended

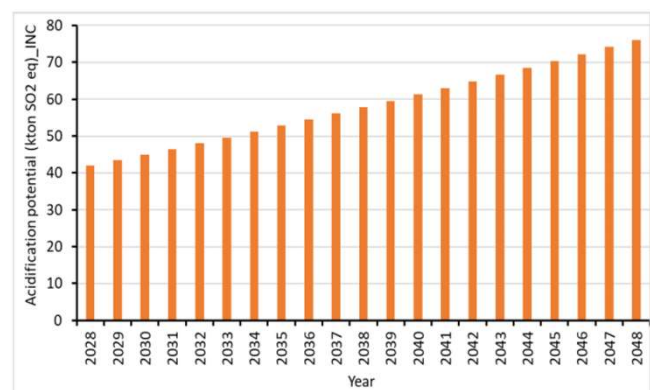


Figure 15. Acidification potential of INC technology

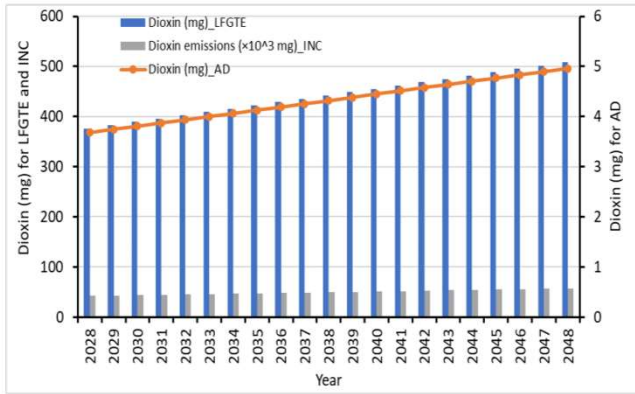


Figure 16. Dioxin potential of WtE systems

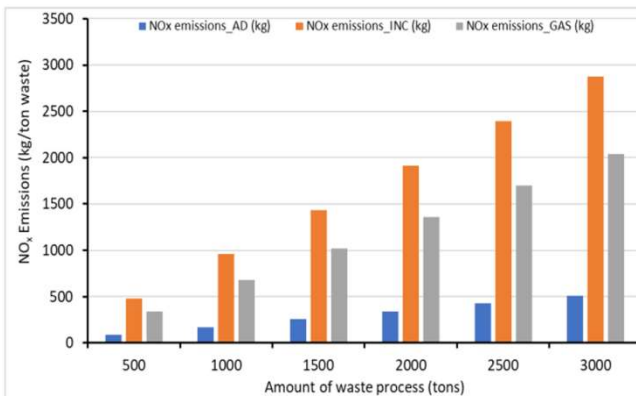


Figure 17. NO_x Emissions from WtE systems

on waste processing rate. Dioxin is one of the most toxic chemicals that responsible for skin cancer, liver, kidney, heart and blood disorder are shown in **Figure 16**. From **Figure 16** refers that AD has the lowest, LFGTE has moderate and INC technology has the highest amount of dioxin emission potential.

Figure 17 shows that the emissions of nitrogen oxides (NO_x) whose are responsible for damaging ecosystem, acid rain and public health. The rate of NO_x emissions from AD, INC and GAS technologies are 0.17, 0.68 and 0.957 kg per ton waste, respectively.

Therefore, overall results of GWP parameters shown in **Figures 12 to 17** reveal that AD technology is environment friendly and INC technology is high emissible options among the WtE systems.

4.3 Discussion

In this research LCC based economic assessment has been analyzed for implementing of WtE systems in Dhaka city. Waste generation rate gradually increases with population growth rate and economic development of any country (Cudjoe and Han, 2020), the results of this study stated that the projected waste generation rises at least 135%

over a 20-year period from 2028 to 2048. This type of assumption can be different from city to city for specific context. For instance, a study on waste amount has predicted in Tehran and Beijing city that MSW rises 340 and 240%, respectively in a period of time (Huang and Fooladi, 2021). AD technology has highest and LFGTE has the lowest electricity generating potential but AD is low carbon emission technology (Ogunjuyigbe et al., 2017; Nubi et al., 2022). This represents their waste streams containing high percentage of food waste that generate huge amounts of biogas for electricity generation. GAS and INC technology has moderate electricity generating potential but INC is high carbon emission technology (Alzate et al., 2019). The WtE technological outcomes indicates that though higher emissions of GHG, globally widely used INC technology is more economic options to reduce waste volume (up to 90%), but AD technology is also economic options with lower carbon emissions. On the other hand, gasification and pyrolysis technology have higher energy recovery potential but faces some challenges of implementation (Singh, 2025). At moderate investment cost, AD is socially acceptable and low carbon emissions technology comparatively gasification and pyrolysis technology, but these required high capital investment. On the other hand, widely adopted INC technology faces several challenges related to high carbon emissions and ash residue management (Olodu et al., 2025). The results of (Madhavaraj and Karthikeyan, 2025) reveal that AD generates more economic benefits from biogas to electricity, district heating, fertilizer, and low emissions, compared to the landfill systems. But hybrid waste management system of LFGTE and AD is also economic and lower GHGs emission options.

Vartiainen et al. (2025) demonstrated that INC technology is economically most feasible solution than landfilling technology based on economic parameters. Abdallah et al. (2018) also concluded that incineration is economically most favorable WtE options than AD technology. On the other hand, Sabeti et al. (2025) show that AD technology is economically feasible options than INC technology based on the outcomes of NPV (4.72 million USD), IRR (17%) and LCOE (0.05USD/kWh). In an Indonesian context, Zeng et al. (2024) assessed the LCOE of INC technology is 0.044USD/kWh which much less than market price and GHGs emissions can be possible to reduce by financial and policy support of the government. Agaton et al. (2020) reveal that waste management through INC (LCOE

0.03USD/kWh) except landfilling is more economic WtE options followed by GAS (LCOE 0.07USD/kWh) and pyrolysis (LCOE 0.12USD/kWh) technology. Pheakdey et al. (2023) are indicated that LCOE value of WtE systems INC, LFGTE, AD are 0.053, 0.07, 0.093 USD/kWh respectively. In addition, INC technology is economically most feasible WtE options according to the outcomes of NPV, PBP and LCOE value than LFGTE and AD technology. Sechoala et al. (2023) are assessed the economic viability and environmental sustainability of INC and AD technology and the results reveal that INC is economically viable than AD technology. AD technology emits lower carbon dioxides and other toxic gases than INC technology. Therefore, AD is environment friendly options than INC technology to minimize global warming potential. The results of present study for Dhaka city are very similar to (Abushammala and Qazi, 2021), who concluded that INC is financially most feasible option compared to GAS and AD technology based on the lowest LCOE value. Again, INC is least preferred WtE option than AD for electricity generation in Nigeria based on economic indicators (Ogunjuyigbe et al., 2017). Mabalane et al. (2021) mentioned that if PBP of WtE system is less than seven years then WtE projects will be economic, but in case of Dhaka city PBP is less than four years except LFGTE technology. The present study indicates that the LCOE of WtE systems is less than market price except LFGTE technology. Hence, all the WtE system is economically feasible in Dhaka city except LFGTE technology but INC technology more economic options among the four technologies.

The variation of the economic parameters is depended on the change of capital cost, operation & maintenance cost and discount rate of WtE systems (Sharma and Chandel, 2021). LCC increases if capital cost and Opex cost increases and vice versa. Again, LCC decreases if discount rate increases and vice versa (Sharma and Chandel, 2021). On the other hand, the findings of (Ayodele et al., 2018) indicates that NPV value varies with the electricity generating potential and electricity unit prices. If electricity generating potential and electricity unit price increases, then NPV increases and positive NPV value define that the WtE systems are economically feasible and profitable.

The variation of capital cost and operational cost of WtE systems may affect the overall electricity generation efficiency and economic scenarios of the WtE systems (Ramos et al., 2020). Additionally, the application of mixed technology combination could increase overall financial

and technical feasibility of co-products of the WtE systems (Mabalane et al., 2021). These waste management strategies are support the clean energy, economic development and environmental sustainability.

The research reported that conditionally WtE systems can be economically profitable and environmentally friendly options for waste management but there are many challenges to implement the systems. There are some recommendations to face the implementation the challenges of these WtE strategies:

- (i) required absolute data for feasible WtE systems.
- (ii) identify the uncertainties of each technology.
- (iii) increase plant capacity and decrease investment and operation cost for economic feasibility.
- (iv) engage central government, local government, communities, private sectors and relevant stakeholders to implement WtE systems.
- (v) use WtE residues for other economic purposes to make the WtE systems more economic.
- (vi) increase community acceptance of WtE systems.
- (vii) increase waste collection and separation by proper authority and non-profit organizations.
- (viii) make trained workforce to operate the WtE systems.
- (ix) introduce small-scale projects before taking large scale WtE projects.

5. Conclusions

The amount of waste generation in Dhaka city increases gradually with the population growth rate and economic development, and after 20-year assessment period (from 2028 to 2048) it will rise up to 135%. Some important findings of this study are:

- (i) AD technology has the highest and LFGTE technology has the lowest electricity generating potential.
- (ii) All the WtE systems are economically viable except LFGTE technology in Dhaka city.
- (iii) INC technology is economically most feasible option among the four technologies. But AD and GAS technology are also moderately economic option.
- (iv) INC technology emits highest carbon dioxide and other toxic gases followed by GAS technology.

(v) AD technology has lowest GHGs emissions compared to other technologies. It is an environment friendly option with high energy efficiency amongst the four WtE systems.

(vi) GAS technology is moderate WtE options based GHGs emissions and energy potential.

(vii) Finally, the outcomes of this study provide an intrinsic information that will help to implement economically viable WtE systems in Dhaka city.

Acknowledgments

The first author would like to thank his PhD Board members: Prof. Dr. Md. Manirul Alam Sarker (Bangladesh University of Engineering and Technology, (BUET)), Prof. Dr. Md. Mustafizur Rahman (BUET), Prof. Dr. Mohammed Forhad Uddin (BUET), Prof. Dr. Rehena Nasrin (BUET) and Prof. Dr. Mohammad Ferdows (University of Dhaka) for their valuable suggestions.

Nomenclature

AD	Anaerobic digestion
Capex	Capital expenditure
CH ₄	Methane
GAS	Gasification
GHG	Green House Gas
INC	Incineration
IRR	Internal rate of return
LCC	Life cycle costing
LCOE	Levelized cost of energy
LCV	Lower calorific value
LFGTE	Landfill gas to energy
NPV	Net present value
Opex	(O & M) Operation and maintenance costs
PBP	Payback period
WtE	Waste-to-energy

Greek symbols

β	Oxidation factor
η	System efficiency
ρ	Density of methane
α	Discount rate

Subscripts

n	Year
p	Price
s	Plant size
t	Time

References

- Abdallah, M., Shanableh, A., Shabib, A., & Adghim, M. (2018). Financial feasibility of waste to energy strategies in the United Arab Emirates. *Waste Management*, 82, 207-219. <https://doi.org/10.1016/j.wasman.2018.10.029>
- Abushammala, M. F. M., & 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(7), 2011-2023. <https://doi.org/10.1007/s10098-021-02099-8>
- Agaton, C. B., Guno, C. S., Villanueva, R. O., & Villanueva, R. O. (2020). Economic analysis of waste-to-energy investment in the Philippines: A real options approach. *Applied Energy*, 275, 115265. <https://doi.org/10.1016/j.apenergy.2020.115265>
- Ahsan, A., Alamgir, M., El-Sergany, M. M., Shams, S., Rowshon, M. K., & Daud, N. N. N. (2014). Assessment of Municipal Solid Waste Management System in a Developing Country. *Chinese Journal of Engineering*, 2014, 561935. <https://doi.org/10.1155/2014/561935>
- Akther, S., Evans, J., & Millington, N. (2025). Solid waste management in Dhaka: Understanding the evolution of a waste regime. *Geoforum*, 165, 104364. <https://doi.org/10.1016/j.geoforum.2025.104364>
- Alao, M. A., Popoola, O. M., & Ayodele, T. R. (2022). Waste-to-energy nexus: An overview of technologies and implementation for sustainable development. *Cleaner Energy Systems*, 3, 100034. <https://doi.org/10.1016/j.CLES.2022.100034>
- Alidoosti, Z., Sadegheih, A., & Saman Pishvae, M. (2025). Comparative Life Cycle Economic Assessment of Treatment Technologies for Converting Municipal Solid Waste into Bio-Energies. *Journal of Engineering in Industrial Research*, 6(4), 352-364. <https://doi.org/10.48309/JEIRE.2025.517322.1199>
- Alzate, S., Restrepo-Cuestas, B., & Jaramillo-Duque, Á. (2019). Municipal solid waste as a source of electric power generation in Colombia: A techno-economic evaluation under different scenarios. *Resources*, 8(1), 51. <https://doi.org/10.3390/resources8010051>
- Ashraf, A. I., Mohareb, E., & Vahdati, M. (2024). Evaluation of life cycle cost for the comparison of decentralized waste to composting and landfilling of municipal solid waste. *Discover Sustainability*, 5(1), 202. <https://doi.org/10.1007/s43621-024-00409-w>
- Ayodele, T. R., Ogunjuyigbe, A. S. O., & Alao, M. A. (2017). Life cycle assessment of waste-to-energy (WtE) technologies for electricity generation using municipal solid waste in

- Nigeria. *Applied Energy*, 201, 200-218.
<https://doi.org/10.1016/j.apenergy.2017.05.097>
- Ayodele, T. R., Ogunjuyigbe, A. S. O., & Alao, M. A. (2018). Economic and environmental assessment of electricity generation using biogas from organic fraction of municipal solid waste for the city of Ibadan, Nigeria. *Journal of Cleaner Production*, 203, 718-735.
<https://doi.org/10.1016/j.jclepro.2018.08.282>
- Beyene, H. D., Werkneh, A. A., & Ambaye, T. G. (2018). Current updates on waste to energy (WtE) technologies: a review. In *Renewable Energy Focus*, 24, 2018, 1-11.
<https://doi.org/10.1016/j.ref.2017.11.001>
- Chowdhury, P., Islam, T., Tasmia, I. J., & Chowdhury, N. U. R. (2025). Power sector transformation in Bangladesh: Paving the pathways towards sustainable development. *Energy Strategy Reviews*, 61, 101829.
<https://doi.org/10.1016/j.esr.2025.101829>
- Chowdhury, T. H. (2021). Technical-economical analysis of anaerobic digestion process to produce clean energy. *Energy Reports*, 7, 247-253.
<https://doi.org/10.1016/j.egyr.2020.12.024>
- Cudjoe, D., & Han, M. S. (2020). Economic and environmental assessment of landfill gas electricity generation in urban districts of Beijing municipality. *Sustainable Production and Consumption*, 23, 128-137.
<https://doi.org/10.1016/j.spc.2020.04.010>
- Escamilla-García, P. E., Camarillo-López, R. H., Carrasco-Hernández, R., Fernández-Rodríguez, E., & Legal-Hernández, J. M. (2020). Technical and economic analysis of energy generation from waste incineration in Mexico. *Energy Strategy Reviews*, 31, 100542.
<https://doi.org/10.1016/j.esr.2020.100542>
- Fernández-González, J. M., Grindlay, A. L., Serrano-Bernardo, F., Rodríguez-Rojas, M. I., & Zamorano, M. (2017). Economic and environmental review of Waste-to-Energy systems for municipal solid waste management in medium and small municipalities. *Waste Management*, 67, 360-374.
<https://doi.org/10.1016/j.wasman.2017.05.003>
- Guendehou, G.H.S., Koch, M., Hockstad, L., Pipatti, R., Yamada, M., Chapter 5: Incineration and Open Burning of Waste, In Volume 5: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published by the Institute for Global Environmental Strategies (IGES), Hayama, Japan on behalf of the Intergovernmental Panel on Climate Change (IPCC), 2006. pages 5.1- 5.26.
- Hemmati, M., Bayati, N., & Ebel, T. (2024). Life cycle sustainability assessment of waste-to-electricity plants for 2030 power generation development scenarios in western Lombok, Indonesia under multi-criteria decision-making approach. *Journal of Building Engineering*, 95, 110335.
<https://doi.org/10.1016/j.jobe.2024.110335>
- Hernández-Romero, I. M., Niño-Caballero, J. C., González, L. T., Pérez-Rodríguez, M., Flores-Tlacuahuac, A., & Montesinos-Castellanos, A. (2024). Waste management optimization with NLP modeling and waste-to-energy in a circular economy. *Scientific Reports*, 14(1), 19859.
<https://doi.org/10.1038/s41598-024-69321-7>
- Huang, W., & Fooladi, H. (2021). Economic and environmental estimated assessment of power production from municipal solid waste using anaerobic digestion and landfill gas technologies. *Energy Reports*, 7, 4460-4469.
<https://doi.org/10.1016/j.egyr.2021.07.036>
- Islam, K. M. N. (2016). Municipal Solid Waste to Energy Generation in Bangladesh: Possible Scenarios to Generate Renewable Electricity in Dhaka and Chittagong City. *Journal of Renewable Energy*, 2016, 1712370.
<https://doi.org/10.1155/2016/1712370>
- Islam, K. M. N. (2018). Municipal solid waste to energy generation: An approach for enhancing climate co-benefits in the urban areas of Bangladesh. In *Renewable and Sustainable Energy Reviews*, Vol. 81, part 2, 2472-2486.
<https://doi.org/10.1016/j.rser.2017.06.053>
- Islam, M. M., Hasanuzzaman, M., Malek, A. B. M. A., Kalam, M. A., & Trianni, A. (2024). *Energy and Economic Impact Assessment of Municipal Solid Waste to Energy in Bangladesh*. <https://doi.org/10.21203/rs.3.rs-3955296/v1>
- Jerin, D. T., Sara, H. H., Radia, M. A., Hema, P. S., Hasan, S., Urme, S. A., Audia, C., Hasan, M. T., & Quayyum, Z. (2022). An overview of progress towards implementation of solid waste management policies in Dhaka, Bangladesh. *Heliyon*, 8(2), e08918.
<https://doi.org/10.1016/j.heliyon.2022.e08918>
- Joarder, S. M., & Mamtaz, R. (2025). Assessment of environmental sustainability of solid waste management system of Dhaka city through life cycle analysis. *Scientific Reports*, 15(1), 36560. <https://doi.org/10.1038/s41598-025-19949-w>
- Kumar, A., & Samadder, S. R. (2017). A review on technological options of waste to energy for effective management of municipal solid waste. In *Waste Management*, 69, 407-422. <https://doi.org/10.1016/j.wasman.2017.08.046>
- Mabalane, P. N., Oboirien, B. O., Sadiku, E. R., & Masukume, M. (2021). A Techno-economic Analysis of Anaerobic Digestion and Gasification Hybrid System: Energy Recovery from Municipal Solid Waste in South Africa. In *Waste and Biomass Valorization*, 12(3), 1167-1184.
<https://doi.org/10.1007/s12649-020-01043-z>

- Madhavaraj, M., & K, K. (2025). Assessment of waste-to-energy strategies for municipal solid waste landfills in Chennai: A case study using energy-economic-environmental (3E) approach. *Cleaner Environmental Systems*, 18, 100321. <https://doi.org/10.1016/j.cesys.2025.100321>
- Manik, M. H. (2024). Demographic and Socio-economic Changes in Bangladesh: Evidence from the Population Census in 2022. *Formosa Journal of Sustainable Research*, 3(1), 29-38. <https://doi.org/10.55927/fjsr.v3i1.5762>
- Mar, K. A., Unger, C., Walderdorff, L., & Butler, T. (2022). Beyond CO₂ equivalence: The impacts of methane on climate, ecosystems, and health. *Environmental Science and Policy*, 134, 127-136. <https://doi.org/10.1016/j.envsci.2022.03.027>
- Mayilsankar, B., Megha, B., & Ramesh, S. T. (2026). Scenario-based evaluation of landfill methane emission and energy generation considering diverse waste and seasonal dynamics. *Clean Techn Environ Policy*, 28 (6), 162. <https://doi.org/10.1007/s10098-026-03516-6>
- Medina-Salgado, M. S., García-Muñiña, F. E., Cucchi, M., & Settembre-Blundo, D. (2021). Adaptive Life Cycle Costing (LCC) Modeling and Applying to Italy Ceramic Tile Manufacturing Sector: Its Implication of Open Innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, 7(1), 101. <https://doi.org/10.3390/JOITMC7010101>
- Mostakim, K., Arefin, M. A., Islam, M. T., Shifullah, K. M., & Islam, M. A. (2021). Harnessing Energy FromThe Waste Produced In Bangladesh: Evaluating Potential Technologies. *Heliyon*, 7(10), e08221. <https://doi.org/10.1016/j.heliyon.2021.e08221>
- Nielfa, A., Cano, R., & Fdz-Polanco, M. (2015). Theoretical methane production generated by the co-digestion of organic fraction municipal solid waste and biological sludge. *Biotechnology Reports*, 5(1), 14-21. <https://doi.org/10.1016/j.btre.2014.10.005>
- Nubi, O., Morse, S., & Murphy, R. J. (2022). Prospective Life Cycle Costing of Electricity Generation from Municipal Solid Waste in Nigeria. *Sustainability (Switzerland)*, 14(20), 13293. <https://doi.org/10.3390/su142013293>
- Ogunjuyigbe, A. S. O., Ayodele, T. R., & Alao, M. A. (2017). Electricity generation from municipal solid waste in some selected cities of Nigeria: An assessment of feasibility, potential and technologies. In *Renewable and Sustainable Energy Reviews*, 80, 149-162. <https://doi.org/10.1016/j.rser.2017.05.177>
- Olodu, D. D., Erameh, A. A., & Ihenyen, O. I. (2025). A Multidimensional Assessment of Waste-to-Energy Technologies: Economic Feasibility, Social Acceptance, and Future Trends of Gasification and Pyrolysis. *International Journal of Multidisciplinary Studies and Innovative Technologies*, 9(1), 14-22. <https://doi.org/10.36287/ijmsit.9.1.3>
- Pheakdey, D. V., Quan, N. Van, & Xuan, T. D. (2023). Economic and Environmental Benefits of Energy Recovery from Municipal Solid Waste in Phnom Penh Municipality, Cambodia. *Energies*, 16(7), 3234. <https://doi.org/10.3390/en16073234>
- Ramos, A. (2024). Sustainability assessment in waste management: An exploratory study of the social perspective in waste-to-energy cases. *Journal of Cleaner Production*, 475, 143693. <https://doi.org/10.1016/J.JCLEPRO.2024.143693>
- Ramos, A., Berzosa, J., Espí, J., Clarens, F., & Rouboa, A. (2020). Life cycle costing for plasma gasification of municipal solid waste: A socio-economic approach. *Energy Conversion and Management*, 209, 112508. <https://doi.org/10.1016/j.enconman.2020.112508>
- Richard Kwame, A., Mulala Danny, S., & Memory, R. (2022). The Threats of Climate Change on Water and Food Security in South Africa. *American Journal of Environment and Climate*, 1(2), 73-91. <https://doi.org/10.54536/ajec.v1i2.568>
- Sabeti, Z., Nosratnejad, S., Mousavi, M., & Mosafieri, M. (2025). Assessment of electricity generation potential and economic analysis through different municipal solid waste management scenarios: a case study. *Biomass Conversion and Biorefinery*, 15(15), 21883–21895. <https://doi.org/10.1007/s13399-022-03525-7>
- Salami L, Susu AA, Patinvoh RJ, & Olafadehan OA. (2011). Characterisation Study of Solid Wastes: a Case of Lagos State. *International Journal of Applied Science and Technology*, 1(3) 47-52.
- Samiul Islam, F. A. (2023). Solid Waste Management System through 3R Strategy with Energy Analysis and Possibility of Electricity Generation in Dhaka City of Bangladesh. *American Journal of Environment and Climate*, 2(2), 23-32. <https://doi.org/10.54536/ajec.v2i2.1767>
- Sechoala, T., Popoola, O., & Ayodele, T. (2023). Economic and environmental assessment of electricity generation using biogas and heat energy from municipal solid waste: A case study of Lesotho. *AIMS Energy*, 11(2), 337-357. <https://doi.org/10.3934/energy.2023018>
- Shams, S., Sahu, J. N., Rahman, S. M. S., & Ahsan, A. (2017). Sustainable waste management policy in Bangladesh for reduction of greenhouse gases. *Sustainable Cities and Society*, 33, 18-26. <https://doi.org/10.1016/j.scs.2017.05.008>

- Sharma, B. K., & Chandel, M. K. (2021). Life cycle cost analysis of municipal solid waste management scenarios for Mumbai, India. *Waste Management*, 124, 293-302. <https://doi.org/10.1016/j.wasman.2021.02.002>
- Silva, L. J. de V. B. da, Santos, I. F. S. dos, Mensah, J. H. R., Gonçalves, A. T. T., & Barros, R. M. (2020). Incineration of municipal solid waste in Brazil: An analysis of the economically viable energy potential. *Renewable Energy*, 149, 1386-1394. <https://doi.org/10.1016/j.renene.2019.10.134>
- Singh, A. K. (2025). Waste To Energy Technologies In Urban Setting: Comparative Analysis Of Environmental And Economic Performance. *African Journal of Biomedical Research*, 28, 1181-1189. <https://doi.org/10.53555/ajbr.v28i2s.7022>
- Slorach, P. C., Jeswani, H. K., Cuéllar-Franca, R., & Azapagic, A. (2019). Environmental and economic implications of recovering resources from food waste in a circular economy. *Science of the Total Environment*, 693, 133516. <https://doi.org/10.1016/j.scitotenv.2019.07.322>
- Sobamowo, G. M., & Ojolo, S. J. (2018). Techno-Economic Analysis of Biomass Energy Utilization through Gasification Technology for Sustainable Energy Production and Economic Development in Nigeria. *Journal of Energy*, 2018, 4860252. <https://doi.org/10.1155/2018/4860252>
- Sohel, M. S., Alam, S., Adnan, Z. H., Hossain, M. A., Sifullah, M. K., & Happy, A. N. (2024). Household Waste Management Woes in Dhaka City: Current Challenges and Policy Directions. *International Journal of Community Well-Being*, 7(2), 237-264. <https://doi.org/10.1007/s42413-024-00208-1>
- Soni, A., Gupta, S. K., Rajamohan, N., & Yusuf, M. (2025). Waste-to-energy technologies: a sustainable pathway for resource recovery and materials management. In *Materials Advances*, 6(14), 4598–4622. <https://doi.org/10.1039/d5ma00449g>
- Vartiainen, T., Kärri, T., Afonso, P., & Happonen, A. (2025). Modeling and Assessing Economical Feasibilities for Waste to Energy Conversion/Incineration Process in Context of Municipal Solid Waste. *Intelligent and Sustainable Manufacturing*, 2(2), 10015. <https://doi.org/10.70322/ism.2025.10015>
- Victoire, A., Martin, N. V., Abias, M., Pacifique, U., & Claude, M. J. (2020). Solid Waste Management Challenges and Its Impacts on People's Livelihood, Case of Kinyinya in Kigali City. *Journal of Geoscience and Environment Protection*, 8(6), 82-96. <https://doi.org/10.4236/gep.2020.86007>
- Yao, X., Guo, Z., Liu, Y., Li, J., Feng, W., Lei, H., & Gao, Y. (2019). Reduction potential of GHG emissions from municipal solid waste incineration for power generation in Beijing. *Journal of Cleaner Production*, 241, 118283. <https://doi.org/10.1016/j.jclepro.2019.118283>
- Zeng, J., Mustafa, A. B., Liu, M., Huang, G., Shang, N., Liu, X., Wei, K., Wang, P., & Dong, H. (2024). Environmental, Energy, and Techno-Economic Assessment of Waste-to-Energy Incineration. *Sustainability (Switzerland)*, 16(10), 4140. <https://doi.org/10.3390/su16104140>