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Exploring Waste to Electricity Technologies for Charging Electric Vehicle in Dhaka City: A Techno-Economic and Environmental Analysis

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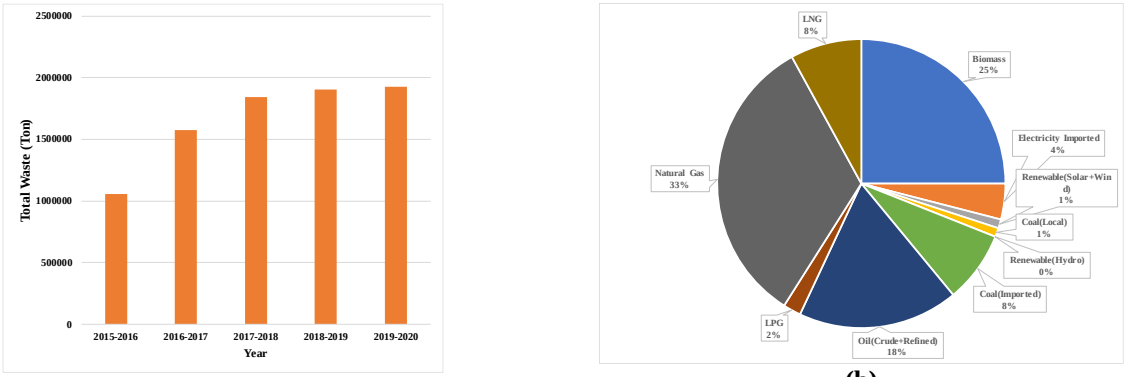
Abstract

The alarming increase in the world's population rate has imposed major challenge to the researchers to properly manage huge amount of waste that are being generated every day. This research focuses on exploring different waste to energy (WtE) options for the Dhaka city which is the capital of Bangladesh. The main objective of this study is to find out the best WtE method for the city to meet the extra electricity demand that will be imposed if the conventional engines of the small-scale vehicles of the city are replaced with batteries. This research begins with finding out the most popular WtE methods for performing techno-economic and environmental analysis. Among the landfill gas recovery (LGR), anaerobic digestion (AD) and incineration (INC) process, AD has the best electricity generation potential (2134027 MWh/y) compared to the other techniques. However, incineration has been found the most economical method. As AD offers 70.25% more electricity than the incineration, AD is selected for Dhaka city to reliably supply the electricity for charging the vehicle. Using AD, it will be able to generate a surplus of 10% electricity. Meanwhile, using INC will cover 65% and LGR will cover 37% of the energy required for charging electric vehicles.

Keywords: Waste-to-Energy, Electric Vehicles, Levelized Cost of Energy, Global Warming Potential.

1. INTRODUCTION

Bangladesh is one of the most populated countries in the world. Because of the large population, a lot of waste is generated daily, which, if left unchecked, can cause environmental pollution[1].Figure 1(a) shows that the waste generation has been on an upward trajectory. Each Fiscal Year (FY) the Dhaka city corporations need to deal with more and more waste[2].These wastes can be turned into electricity using proper methods. Figure 1(b) shows only 25% of the waste biomass is used for energy production in Bangladesh[3].So there is a huge wasted potential which can be harnessed through the use of waste-to-energy (WtE) technologies.



(a) **(b)**

Figure 1: (a)Total waste collection in Dhaka, (b) Share of total primary energy of Bangladesh (FY 2022-2023)

Landfill Gas Recovery (LGR), Waste Incineration (INC), and Anaerobic Digestion (AD) are the most prominent WtE methods[4]. Therefore, having a WtE plant will help to manage and fulfill the country's energy needs in the long run[5]. Table 1 summarizes some of the key studies in recent years on WtE technologies.

Table 1. Recent studies on different WtE technologies.

Year	Country /Place	Methods	Electricity (GWh/Yr)	Cost (USD/kWh)	Population	Remarks	Ref.
2017	Abuja, Nigeria	LGR INC AD	112.55 53.84 125.73	0.0413 0.2033, 0.0177	1406239	Landfill has been found the most economical	[6]
2012	Accra, Ghana	INC LGR Pyrolysis	2 1.5	0.51 0.26	24.7 Million	LGR offers the most favorable power-to-cost ratio.	[7]
2021	Cias Centro Oeste, Brazil	LGR AD	12.356 1.619	0.2	580000	WtE generation is capable of sustaining the entire area.	[8]
2020	Ahvaz, Iran	AD LGR	3.214 1.674	--	1,302,591	2% household electricity can be obtained from WtE.	[4]
2020	Beijing, China	AD LGR	734.91 502.15	0.0739 0.1413	20 million	Both works great but AD will be better because of less cost.	[9]
2020	Mexico	INC	386.91	--	3 million	Substantial energy generation but economic feasibility is harder to maintain.	[10]
2018	Kathmandu, Nepal	INC LGR Pyrolysis Plasma Arc	0.0128 0.016 0.0135 0.0192	0.095 0.072 0.084 0.065	2,100,000	Plasma Arc technology is by far the best method to use in this case.	[11]
2015	South Africa	INC LGR	11607 5388	--	53.15 million	WtE is beneficial but doesn't have the infrastructure for it.	[12]
2017	Chittagong, Bangladesh	INC LGR	762.74 138.55	--	3.76 million	WtE will help reduce emission while producing energy.	[1]

From the studies it is seen, that in Nigeria, LGR, INC, and AD methods were applied to harness electricity from municipal solid waste [6]. Considering the economic viability of AD, it is the first choice among all Nigeria locations[6].As INC showed the highest levelized-cost-of-energy (LCOE), it is less economical compared to the other two. By analyzing the feasibility of LGR and INC WtE technology, it is evident that using WtE technology will be more economical and environmentally friendly than the traditional power plants[6]. Most of the studies are focused on implementing LGR, INC, and AD as observed in the **Table 1**. Still, a few other technologies like Pyrolysis and Plasma Arc Gasification are being also considered in some cases. The study done on Kathmandu, the capital of Nepal, uses the Plasma Arc Gasification and Pyrolysis technology[11]. Even though the Pyrolysis is not worth the cost, the Plasma Arc Gasification showed some potential as it had lower LCOE and a relatively high amount of energy generation prospect[11].

Most of the studies that are focused on WtE technology (INC, LGR, AD) produce it to supply the grid. However, with the increasing number of vehicles and the global shift towards electric vehicles (EVs), it is a good time to conduct a techno-economic analysis to find out if these WtE technology can effectively sustain a substantial number of EVs in this country. One of the biggest problems with using traditional fuels is the environmental pollution associated with it. This study, for the first time, explores the viability of different WtE strategies in terms of energy, economy and environmental aspects to charge the EVs in Dhaka city, Bangladesh.

2. Methodology

This study examines the potential of Electric Vehicle (EV) adoption in Dhaka city, selected due to its high vehicle density. As the capital of Bangladesh, Dhaka hosts the largest number of vehicles and industries compared to any

other city in the country. Therefore, insights gained from analyzing Dhaka's EV potential can be effectively extended to other cities across the nation.

2.1 Energy Estimation

Landfill Gas Recovery: The amount of methane generation per year basis has been calculated using the following equation[6]:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o(\frac{OFW_{LGR}}{10})e^{-kt_{ij}} \quad (1)$$

Here, $i$is the 1-year time increment, j is the 0.1-year time increment, n is the total year considered, t_{ij} is the age of the jth section of waste in the year i,k is the annual methane generation rate,L_o is the methane generation potential in m^3/Mg, and OFW_{LGR}(Mg)is the organic fraction of the waste that have been land filled.

The methane that is generated from the landfill can be used to determine the approximate electricity generation (kWh/yr). The following equation is used for this process[6]:

$$E_{P_LGR} = \frac{LHV_{CH_4} \times Q_C \times \varphi_1}{\varphi_2} \quad (2)$$

Here, $LHV_{CH_4}$is the lower heating value of methane which is taken 37.2MJ/m^3,Q_C (m^3/yr) is theaverage methane collection per year.φ_1 is the electrical conversion efficiency of the engine and it is taken as 0.33,andφ_2 represents the MJ to kWh conversion factor.

Incineration: The heat output from INC is denoted with Q_{INC} and this can be estimated in (BTU/h) from the following equation[13]:

$$Q_{INC} = \frac{b \times HHV(100-e)}{100} \quad (3)$$

Here,b(lb/h) is the dry waste supplied to the incineration plant, HHV(BTU/lb) is the higher heating value of the dry waste, and e is the sum of all the efficiency losses.

Using the heat outputQ_{INC}, It is possible to estimate the electricity generation using a steam turbine. Here is the equation that is used[14]:

$$E_{P_INC} = \frac{Q_{INC} \times \eta \times 8760}{3412.14} \quad (4)$$

The efficiency η for the steam turbine was taken as 0.29.

Anaerobic Digestion: Total methane generation in kg for AD can be estimated using the following equation:[6]

$$M_{CH_4} = \frac{16 \times D_3}{(M_C \times p)+(M_H \times q)+(M_O \times r)+M_N} \times 1000 \quad (5)$$

Here, $M_C, M_H, M_O and M_N$ represent the molar masses of carbon, hydrogen, oxygen, and nitrogen, respectively.

Using the M_{CH_4} value it is possible to calculate the total methane generation volume (m^3/y) for AD using the following equation[6]:

$$V_{CH_4} = \frac{M_{CH_4}}{\rho_{CH_4}} \times OFW_{AD} \quad (6)$$

Here, ρ_{CH_4} is the methane density which is taken 0.717 kg/m^3 and OFW_{AD} is the organic portion of waste.

The estimated electricity generation for AD is finally calculated from[6]:

$$E_{P_AD} = \frac{LHV \times V_{CH_4} \times 0.85 \times \eta_{generator}}{C} \quad (7)$$

Here,LHV is the Lower Heating Value of methane which is taken as 37.2 MJ/m^3,$\eta_{generator}$ is the efficiency of the gas fired generator whose value is assumed to be 0.26, and C is taken 3.6 which is used as the MJ to KWh conversion factor.

2.2 Cost Analysis

Net Present Value (NPV): NPV is all the costs that will be incurred throughout the lifecycle of the plant. It is determined using the following equation[15]:

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} \tag{8}$$

Here, N represents the total life cycle of the plant ($20\ yrs$),r is the annual discount rate and C_n is the cash flow rate.

Levelized Cost of Energy: LCOE is the minimum cost of energy in USD/kWh of energy. The LCOE for all the technologies discussed here can be measured using the following equation[15]:

$$LCOE = \left(\frac{LCC}{E_P}\right) \times RF \tag{9}$$

Here, LCC is the life cycle cost of the project (20 yrs), RF is the capital recovery factor whose value is 0.0513 and E_P is the amount of energy generated from each of the technologies.

Payback Period: PB is the duration that is required for the cost to break even. It is calculated in year, and all the technologies can use the same equation to calculate the PB. The following equation is used to estimate PB[16]:

$$PB = \frac{Inv - Rebates}{AnnualEnergySavings\ (\$/yr)} \tag{10}$$

Global Warming Potential (GWP): GWP is the measure of how much heat the greenhouse gases will entrap compared to CO_2 [17]. GWP is different for every technology and different formula is used for different technology. GWP for LGR is calculated from following equation[18]:

$$GWP_{LGR}(kgCO_2eq) = V_{CH_4} \times 0.75 \times GWP_{CH_4} \times 0.25 \times 6.67 \times 10^{-4} \times 1000 \tag{11}$$

Here, GWP_{CH_4} is the GWP of methane relative to CO_2which is taken as 25 kg, Methane collection efficiency is assumed 0.75,only 25% of the generated methane will be released to the atmosphere so 0.25 is used, and 6.67×10^{-4} is the conversion factor from m^3 to ton.

For GWP, it is considered that 5% of the produced methane was leaked from the digester. GWP for AD technology is calculated from the following equation [6]:

$$GWP_{AD}(kgCO_2eq) = V_{CH_4} \times 0.05 \times GWP_{CH_4} \times 0.717 \tag{12}$$

For INC, the emission factor of methane was taken as 30 kg/TJ [19]. GWP for INC technology is calculated using the following equation[20]:

$$GWP_{INC}(kgCO_2eq) = b \times GWP_{CH_4} \times LHV \times E_{CH_4} \tag{13}$$

Here, E_{CH_4} represents the emission factor of methane which is taken as 30 kg/TJ.

Electricity Demand: Electricity demand is the required electricity needed to fully charge all the EVs that is taken for this study.

$$Demand = Average\ travel\ distance \times Energy\ Per\ Distance \times Number\ of\ Vehicles \tag{14}$$

3. RESULTS AND DISCUSSION

In Dhaka, the capital of Bangladesh, both North and South City Corporations oversee so that wastes are properly collected. According to the national statistics, around 80% of the waste is collected from all the areas[21, 22]. From the Statistical Yearbook 2021, the data for small-scale vehicles (private cars, microbus, taxicabs, and ambulances) was taken. [23]. Annual electricity generation, the volume of methane collection along with investment and revenue has been determined. Table 2 shows all the data that have been used for the study.

Table 2. Data used in this study.

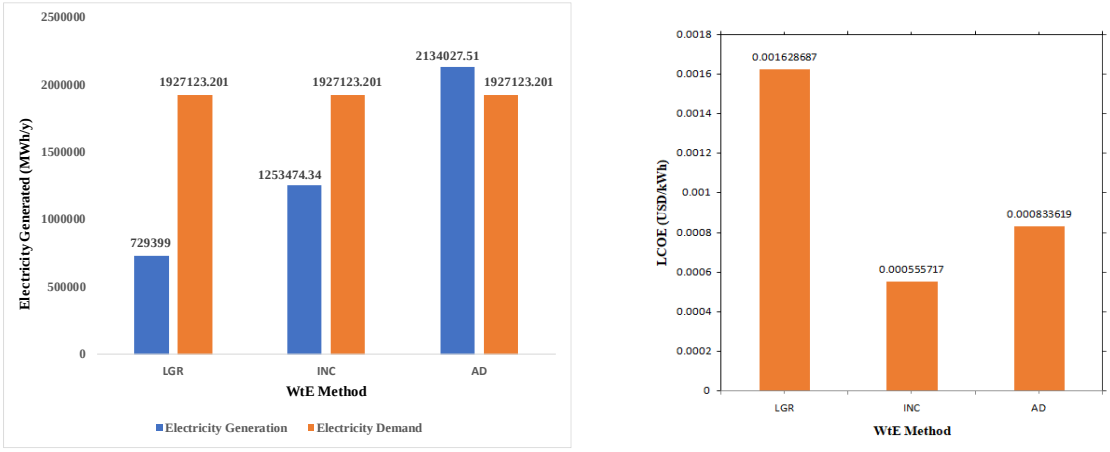
Study Area	Waste (ton/y)[21, 22]	Inflation Rate[24]	Cost of Electricity($ /kWh) [25]	No of Vehicles [23]	Vehicle Electricity Demand/y(MWh)[26]	Average Travel Distance(Km/Year)[27]
Dhaka, Bangladesh	1,929,661	9.74%	0.063	534025	1927123.201	15291

The techno-economic and environmental analysis has been done for a 20-year frame. Table 3 Summarizes all the data calculated during the study.

Table 3. Energy generation estimation and cost analysis for LGR, AD, and INC.

	LGR	INC	AD
Methane Volume(m^3/y)	2.85×10^8	--	9.34×10^8
Investment (m$)	18.35	271.81	694.19
Revenue (m$)	145.85	1579.38	2688.88
Payback Period (yr)	4.17	3.44	5.16
GWP (kg CO2-eq/yr)	891695625	8756379	837522473.2

As illustrated in Figure 2(a), the estimated demand is relatively high(1927123.201 MWh) to charge all the EVs considered for the study. Using AD technology it is possible to meet the demand and also have a surplus (10%) amount which then can be directed towards the grid. However, the LGR and INC have not been able to fill up the energy demand for considered EVs. INC is estimated to cover 65% of the demand while LGR only covers 37%.Comparing the initial investment cost of the three technologies, AD has the highest cost associated to it. INC places in the middle in terms of the initial cost and LGR has the lowest initial cost among the three. Even though AD has the highest initial cost, it also has by far the best profit margin. As a result, it is possible to get payback from the technology in a relatively short amount of time. For INC the payback period is the lowest at 3.44 years. LGR is the intermediate one with 4.17 years. However, AD is not too far behind at 5.16 years.Figure 2(b) represents LCOE, which is the average cost of energy generation, for various WtE strategies. INC technology is the cheapest option available while LGR is the costliest.Even though the initial investment cost is a lot lower,LGR has almost double LCOE. Another downside is it hasa lot less energy generation compared to the other two. Meanwhile, AD strikes a balance, being in the middle of these two technology in cost. Considering both Figure 2(b) and Table 3revenue sectionit is observed that AD has by far the best profit margin. Though the initial investment cost is a lot higher for AD compared to the other two technologies, the energy production is almost double compared to INC. So, AD has been chosen as the best technology for this study. To validate this study, a literature review has been done. From there it is found AD has often been the best technology for electricity generation [11, 23, 28] which coincides with our analysis. Table 3 also outlines the GWP for each technology.A typical passenger vehicle has a GWP of 4600 kg CO2-eq/yr[29]. Considering this data, the amount of vehicles in this study will produce about 2.47 billion kg CO2-eq/yr. However, using EVs reduces that value to only 0.89 billion kg CO2-eq/yr. Thus EVs are significantly more environmentally friendly than typical fuel-based vehicles. Future strategies should focus on integrating AD with renewable energy sources like solar and wind to develop a hybrid energy system, ensuring stability, efficiency, and sustainability while reducing reliance on a single source. Additionally, enhancing waste collection infrastructure and exploring advanced co-digestion technologies could further optimize AD efficiency, reduce costs, and maximize energy output, paving the way for a cleaner and more sustainable urban future.



(a) **(b)**

Figure 2:(a) Estimated Energy Generation vs Demand, (b) LCOE of different WtE technology.

4. CONCLUSIONS

This study evaluates the potential of different WtE technologies for charging EVs while considering the economic and environmental impact. To meet the energy demand for EVs in Dhaka city, AD is the most efficient and profitable of the three technologies in this study. Although it has a higher initial investment cost compared to the other two, it also has the best profit margin. AD also generates surplus 10% amount which can be contributed to the grid. As a result, it has a reasonable payback period of 5.16 years. In contrast, INC and LGR fall short of meeting the energy demand with 65% and 37% coverage respectively. AD's balance of cost and energy production outperforms the alternatives. The environmental benefit is also evident from the study. Traditional vehicles produce 2.47 billion kg CO2-eq/yr greenhouse gas but using the EVs reduces it significantly. Comparatively, AD has the intermediate level of emission among the three producing 0.84 billion kg CO2-eq/yr. Even though it's not the lowest among the three, the lowest being INC with 0.0088 billion kg CO2-eq/yr, AD is still significantly lower than traditional vehicles. Thus, it will not only meet the EV energy demand for Dhaka city but also reduce vehicle emissions, benefiting the environment.

5. REFERENCES

[1] K. M. N. Islam, "Municipal solid waste to energy generation: An approach for enhancing climate co-benefits in the urban areas of Bangladesh," *Renewable and Sustainable Energy Reviews*, vol. 81, pp. 2472-2486, 2018, doi: 10.1016/j.rser.2017.06.053.

[2] D. C. C. Bangladesh. "Dhaka City Corporation Waste Report." Dhaka City Corporation Bangladesh. https://dncc.gov.bd/site/view/annual_reports/- (accessed.

[3] E. a. M. R. D. Bangladesh. "Energy Scenario of Bangladesh 2022-23." Energy and Mineral Resources Division. https://hcu.portal.gov.bd/sites/default/files/files/hcu.portal.gov.bd/publications/ae775b7e_b63d_491d_81e4_b317ff8e11ca/2024-07-15-09-11-d13a3451b969fb9a3c5c74e9130c9f6c.pdf (accessed.

[4] S. M. Safieddin Ardebili, A. Asakereh, and M. Soleymani, "An analysis of renewable electricity generation potential from municipal solid waste: a case study (Khuzestan Province, Iran)," *Biomass Conversion and Biorefinery*, vol. 13, no. 1, pp. 89-97, 2020, doi: 10.1007/s13399-020-01011-6.

[5] F. Ahmed, S. Hasan, M. S. Rana, and N. Sharmin, "A conceptual framework for zero waste management in Bangladesh," *International Journal of Environmental Science and Technology*, vol. 20, no. 2, pp. 1887-1904, 2022, doi: 10.1007/s13762-022-04127-6.

[6] A. S. O. Ogunjuyigbe, T. R. Ayodele, and M. A. Alao, "Electricity generation from municipal solid waste in some selected cities of Nigeria: An assessment of feasibility, potential and technologies," *Renewable and Sustainable Energy Reviews*, vol. 80, pp. 149-162, 2017, doi: 10.1016/j.rser.2017.05.177.

[7] C. Ofori-Boateng, K. T. Lee, and M. Mensah, "The prospects of electricity generation from municipal solid waste (MSW) in Ghana: A better waste management option," *Fuel Processing Technology*, vol. 110, pp. 94-102, 2013, doi: 10.1016/j.fuproc.2012.11.008.

[8] R. C. de Brito, R. M. Barros, I. F. S. dos Santos, G. L. Tiago Filho, and S. P. G. da Silva, "Municipal solid waste management and economic feasibility for electricity generation from landfill gas and anaerobic reactors in a Brazilian state," *Environmental Technology & Innovation*, vol. 22, 2021, doi: 10.1016/j.eti.2021.101453.

[9] D. Cudjoe, M. S. Han, and A. P. Nandiwardhana, "Electricity generation using biogas from organic fraction of municipal solid waste generated in provinces of China: Techno-economic and environmental impact analysis," *Fuel Processing Technology*, vol. 203, 2020, doi: 10.1016/j.fuproc.2020.106381.

[10] P. E. Escamilla-García, R. H. Camarillo-López, R. Carrasco-Hernández, E. Fernández-Rodríguez, and J. M. Legal-Hernández, "Technical and economic analysis of energy generation from waste incineration in Mexico," *Energy Strategy Reviews*, vol. 31, 2020, doi: 10.1016/j.esr.2020.100542.

[11] A. M. Nakarmi and K. B. Sodari, "Electricity Generation Potential of Municipal Solid Waste of Nepal and GHG Mitigations," *Journal of the Institute of Engineering*, vol. 14, no. 1, pp. 151-161, 2018, doi: 10.3126/jie.v14i1.20079.

[12] N. Scarlat, V. Motola, J. F. Dallemand, F. Monforti-Ferrario, and L. Mofor, "Evaluation of energy potential of Municipal Solid Waste from African urban areas," *Renewable and Sustainable Energy Reviews*, vol. 50, pp. 1269-1286, 2015, doi: 10.1016/j.rser.2015.05.067.

[13] J. Jorgenson, P. Gilman, and A. Dobos, "Technical Manual for the SAM Biomass Power Generation Model," 2011. [Online]. Available: https://www.osti.gov/biblio/1026561.

[14] A. Gómez, J. Zubizarreta, M. Rodrigues, C. Dopazo, and N. Fueyo, "Potential and cost of electricity generation from human and animal waste in Spain," *Renewable Energy*, vol. 35, no. 2, pp. 498-505, 2010, doi: 10.1016/j.renene.2009.07.027.

[15] W. Short, D. J. Packey, and T. Holt, "A manual for the economic evaluation of energy efficiency and renewable energy technologies," United States, 1995. [Online]. Available: https://www.osti.gov/biblio/35391

[16] I. L. Wong, P. C. Eames, and R. S. Perera, "A review of transparent insulation systems and the evaluation of payback period for building applications," *Solar Energy*, vol. 81, no. 9, pp. 1058-1071, 2007/09/01/ 2007, doi: https://doi.org/10.1016/j.solener.2007.04.004.

[17] Government of Canada. "Global warming potentials." Govt. Canada. https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/quantification-guidance/global-warming-potentials.html (accessed 8 August 2023.

[18] T. R. Ayodele, A. S. O. Ogunjuyigbe, and M. A. Alao, "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*, vol. 203, pp. 718-735, 2018, doi: 10.1016/j.jclepro.2018.08.282.

[19] T. R. Ayodele, A. S. O. Ogunjuyigbe, and M. A. Alao, "Life cycle assessment of waste-to-energy (WtE) technologies for electricity generation using municipal solid waste in Nigeria," *Applied Energy*, vol. 201, pp. 200-218, 2017/09/01/ 2017, doi: https://doi.org/10.1016/j.apenergy.2017.05.097.

[20] D. Cudjoe and P. M. Acquah, "Environmental impact analysis of municipal solid waste incineration in African countries," *Chemosphere*, vol. 265, p. 129186, 2021/02/01/ 2021, doi: https://doi.org/10.1016/j.chemosphere.2020.129186.

[21] Dhaka North City Corporation. "Waste Report 2019-2020." DNCC. https://dncc.portal.gov.bd/sites/default/files/files/dncc.portal.gov.bd/annual_reports/826bcbc3_59aa_4eed_9cb7_16c254d180d1/2021-12-22-08-41-89a35db9d8246b8cc971978cea774687.pdf (accessed 07 August 2023.

[22] Dhaka South City Corporation. "Waste Management Report 2019-2020." DSCC. https://dscc.portal.gov.bd/sites/default/files/files/dscc.portal.gov.bd/page/0f15210b_7f78_4452_9577_51928ded5f2e/2021-10-07-10-26-d26bed6c3ecf48605fc2a8192d2e8c93.pdf (accessed 7 August 2023.

[23] Statistical Yearbook Bangladesh 2021. "Statistical Yearbook Bangladesh 2021." BBS. https://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/b2db8758_8497_412c_a9ec_6bb299f8b3ab/2022-06-15-10-49-3cf641425dd693f9e954de5ae9470775.pdf (accessed 7 August 2023).

[24] Bangladesh Bank. "Inflation in Bangladesh." BB. https://www.bb.org.bd/en/index.php/econdata/inflation (accessed 26 Aug, 2023).

[25] Bangladesh Electricity Depelopment Board. "Bangladesh Gazette 2023." BEDB. https://bpdb.portal.gov.bd/sites/default/files/files/bpdb.portal.gov.bd/page/4a0f045a_1415_45f1_9e7c_02a8ed4f103c/2023-03-19-09-42-a28f6e03ffd4eb321bcf875bcc7c650f.pdf (accessed 20 Aug, 2023.

[26] M. Rahman, *Fuel consumption of transport sector: how the people of Dhaka City will be moving in the future?* 2009.

[27] "Average Annual Miles per Driver by Age Group." https://www.fhwa.dot.gov/ohim/onh00/bar8.htm (accessed.

[28] L. P. Joseph and R. Prasad, "Assessing the sustainable municipal solid waste (MSW) to electricity generation potentials in selected Pacific Small Island Developing States (PSIDS)," *Journal of Cleaner Production*, vol. 248, 2020, doi: 10.1016/j.jclepro.2019.119222.

[29] U. S. E. P. Agency. "Greenhouse Gas Emissions from a Typical Passenger Vehicle." United States Environment Protection Agency. https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle#:~:text=A%20typical%20passenger%20vehicle%20emits,of%20miles%20driven%20per%20year. (accessed 09 October,2024.