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Transformation of Waste into Energy in Pabna Municipality Area of Bangladesh: An Economic Valuation

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Abstract

As society becomes more affluent and urbanized, communities become more congested and waste composition becomes more complex, making it problematic through continued dumping. As a typical scenario of waste mismanagement and negative environmental impacts from the landfill waste in Pabna city, reducing GHGs emissions from landfilling and developing renewable energy supplies is essential. This study sets its objectives to assess the perceptions and preferences for waste management in Pabna, evaluate differences between landfilling and Waste-to-energy (WTE) in terms of economic and environmental costs and benefits and explore the range of parameters that support the feasibility of WTE. This study carried out both the secondary data and household interviews (n=301), followed by a structured questionnaire and used the First Order Decay Model, cost-benefit analysis and sensitivity analysis to generate an empirically supported assessment. Provision of tipping fees, waste tax, willingness to pay for waste collection and electricity bills for using electricity generated from the waste can help improve waste transformation into an energy project in the Pabna city. This study considers specific and relevant transformation ways of waste into energy to generate empirically supported explanations, identify the negative impacts of open dumping of waste and formation of waste policy in the Pabna city of Bangladesh. The findings of this study will provide a robust basis for policymakers, planners, researchers, government and development partners for further research, project implementation of the transformation of waste into energy, developed specified policies to lessen the emission of GHGs, building resilient and sustainable waste management and establish a low carbon society.

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1. Introduction

Waste is a part of the natural environment, but it is becoming a severe issue in urban areas of developing countries. Urban areas of Bangladesh have been experiencing rapid population and economic growth, leading to unprecedented consumption and waste generation. Like the other urban areas of Bangladesh, the Pabna Municipality area is facing a waste management crisis. Alongside the more significant quantities of waste, the characteristics and composition of waste are also becoming more complex. As societies become more affluent and urbanized, communities become more congested, and the waste composition becomes more complex-with greater portions of plastics, and other mixed and processed materials-which makes it problematic to continue dumping or burying waste (Klar et al., 2014). More alarmingly, only 40% of disposal sites in the world have leachate treatment, and fewer have gas collection systems. This meant that most disposal sites released untreated and potentially toxic leachate directly into the waterways or soil, and harmful greenhouse gases like methane and carbon dioxide are being passively released into the atmosphere or building up in the landfill, creating a risk for explosion (AusAID, 2011). Aside from GHGs emissions, the dangers of the negative impacts of improper waste management on society and the environment are also driving action for improving waste management strategies. Solid waste in landfills is from mixed streams and not sorted, allowing chemicals and harmful metals to mix with organic degradable materials. The leachate or liquid run-off produced in landfills can be toxic and seep into the soil and water supply. Heavy metals, pathogens and other hazardous substances can also contaminate the environment. Noxious odours and pests are additional nuisances to nearby communities. It is the responsibility of the local government to manage official waste disposal sites. Still, low political will and commitment, lean budgets, inadequate human resources and loose regulation often relegate waste management to low priority in political agendas (Damanhuri, 2005). Poor city governance of waste management, absence of Waste Law, low political priority, insufficient financing, and human behaviour in Pabna City are responsible for environmental degradation. The contamination of surface and groundwater expresses the environmental degradation in this area through leachate, soil contamination through direct waste contact or leachate, and air pollution by burning waste. Every household in this area dumped waste indiscriminately in the streets or the drains and later, collected solid waste by Pabna Municipality on land in a more uncontrolled manner. Such practice also negatively impacts public health and causes economic and welfare losses. Diarrhoea, cholera, dysentery, asthma, scabies and etching result from mismanagement of waste, and most people frequently suffer from these diseases. Disease-affected people cannot participate vigorously in any income-generating activity; hence they lose their living standard.

Land scarcity and exponential waste growth make stop-gap measures such as expanding landfills more complex and costlier. High land prices and dense communities are removing expansion as an option. In addition, the impact of the waste sector on climate change is another driver for improving waste management. Bangladesh ratified the Kyoto Protocol in 1997, followed by the United Nations Framework Convention on Climate Change (UNFCCC), committing itself to reduce its emissions. The primary emission from the waste sector is methane, which has 28 times the global warming potential of carbon dioxide (Global Carbon Project, 2013). Environmentally sound and sustainable waste management is one of Bangladesh's target strategies for reducing GHG emissions.

Solid waste management in Pabna is facing serious challenges. In particular, the practice of landfilling is unsustainable and no longer an adequate solution because of its adverse impacts on society and the environment. A new strategy is needed, and waste into energy through incineration can be a triple-pronged strategy that simultaneously provides long-term sustainable waste management, reduces GHGs emissions from waste and is a new source of renewable energy for the Pabna. Waste into energy by incineration is a proven and popular strategy for developed economies but has limited application in developing countries (Williams, 2011). Thus, waste into energy can be a potential solution for Pabna that can provide environmentally sustainable waste management, reduce emissions and waste in landfills, enhance income-generating capacity, and promote a feed-in tariff system and renewable energy.

This study sets its objectives to assess the perceptions and preferences for waste management in Pabna, evaluate differences between landfilling and transformation of waste into energy in terms of economic and environmental costs and benefits, and investigate the parameters in which transformation of waste into energy is a feasible alternative to landfilling in Pabna Municipality area and explore the range in parameters that will support the feasibility of the transformation of waste into energy.

2. Literature Review

Like the other cities of Bangladesh, Pabna Municipality has no Solid Waste Law. The Government of Bangladesh (GoB), the World Bank, Japan International Cooperation Agency (JICA) and other development partners of Bangladesh took many initiatives for proper solid waste management (SWM) schemes in the different urban areas of Bangladesh. These initiatives are laudable, but several weaknesses exist in implementing adequate waste management. Prior research on waste in Bangladesh finds that institutions and services are poorly organized and inadequate. This is reflected in waste's low political priority and insufficient financing.

Consequently, mismanagement and uncollected waste are dumped indiscrim-

inately in the streets and drains, contributing to flooding, breeding of insect and rodent vectors and spreading of diseases (UNEP-IERC, 1996). Collected municipal solid waste in Bangladesh has been dumped on land more or less uncontrolled manner. Such practice creates serious environmental problems that affect the health of humans and animals and cause severe economic and other welfare losses (Zurbrügg, 2002). The contamination of surface and groundwater can express the environmental degradation caused by inadequate disposal of waste through leachate, soil contamination through direct waste contact or leachate, air pollution by burning of wastes, spreading of diseases by different vectors like birds, insects and rodents or uncontrolled release of methane by anaerobic decomposition of waste. Several studies explored improvements and alternatives for waste management, but these have limitations and cannot address waste issues at the scale. Waste-to-energy (WTE) by incineration is a proven and popular strategy for developed economies but has limited application in developing countries (Williams, 2011). WTE can be a potential solution for Bangladesh that can provide environmentally sustainable waste management, reduce emissions and waste in landfills, enhance income-generating capacity and green growth and provide renewable energy.

3. Materials, Methods and Results

This section will be divided into three parts- scope of the research, description of the study area, data description and the analytical approach.

3.1 Scope of the research

This research aims to compare the costs and benefits to local governments and the greater society of two final treatment scenarios for municipal solid waste in Bangladesh: landfilling versus transforming waste into energy. As defined by the Intergovernmental Panel on Climate Change (IPCC), municipal solid waste (MSW) is waste from households, gardens and parks and commercial or institutional entities such as schools and businesses (IPCC, 2006). Wastewater, industrial waste, toxic/hazardous waste, medical waste, construction and demolition waste and disaster waste are outside this study's scope.

3.2 Description of the study area

Pabna Municipality, Bangladesh, is selected as the case study site because its population, waste characteristic and challenges with waste management are conditions faced by nearly all urban centres in Bangladesh. Thus, findings and lessons extracted from the Pabna study can be applied to other cities in Bangladesh. Pabna city is located in the Northwest region of Bangladesh.

Central Pabna City is bounded by the Government Edward College in the

North, the Icchamoti River in the East, Pabna Mental Hospital in the West and Bus Terminal in the South. It is approximately 223 km away from Dhaka, the capital city of Bangladesh. The population growth rate in Pabna is 3.00, much higher than the national growth rate of 1.22 in 2013 (BBS, 2012; World Bank, 2013). Urbanization and domestic migration from other regions into Pabna City contribute to Pabna's higher population growth. The current population and waste trends for Pabna are summarized in Table 1. Collected waste dumped in this City at Fakirpur, Chetonermore and Banglabazar. Fakirpur is a giant landfill of garbage. It is away from approximately 12 km away from the centre point of Pabna City. This landfill began operations in 2003 and was initially designed as 10 hectares and capacity to hold 2 million m^3 of waste. It had an expected life of 14 years (2003-2016), but the landfill reached capacity earlier than planned. This study depends upon the Fakirpur landfill for the economic valuation of the transformation of waste into energy.

Table 1: Population and waste data in Pabna city

Year	Population	Population change	Waste collection (tones/year)	Daily waste collection (tones/day)	Annual waste collection change from the prior year
2011	3,87,675	0.233306	144,121	395	0.041743165
2001	3,14,338	-	138,346	379	-

Source: *Pabna Municipality, 2015; BBS, 2012*

3.3 Data Description

This study employed qualitative analysis to determine society's view on waste issues and interests in addressing the challenges. Findings from the qualitative research are further applied to policy considerations. The qualitative data were obtained through focus group discussion, random survey questionnaires and personal interviews.

3.3.1 Focus group discussion (FGD)

The focus group discussion's objectives were to understand better the nuances of household waste management practices and challenges and to contribute to developing a relevant questionnaire survey. Participants in the focus group discussion were heads of locality and heads of households. The focus group participants provided first-hand individual experiences and practices with waste management that helped inform the design and content of the survey questionnaire and suggest the appropriate attribute levels used in the questionnaire. The focus group was held on 23 March 2015 and lasted three hours. There were 12 participants and one discussion facilitator, a representative from Pabna Municipality.

3.3.2 Survey through questionnaire

A survey questionnaire was conducted to identify waste management and waste disposal activities, measure the public's perception of the waste management services in Pabna City and provide information about current waste final disposal challenges and potential new waste management programs. The target respondents were adult household members with homes in Pabna and business owners or managers with businesses in Pabna. Respondents were randomly selected from throughout the City. The survey was carried out in April 2015 through face-to-face interviews. The final sample size was 201, comprising 160 households and 41 businesses.

3.3.3 Interview questions

This study also conducted interviews with local and national officials from May to June 2015 to better understand waste management policies, processes, and priorities. Individuals interviewed included bilateral donors, national ministry officials, experts from Bangladesh's Waste and Climate Change working group and local government officials working in waste management. Interview topics included the evolution of waste management policy, background and history of waste disposal sites, budgeting and finance for waste services, inter-agency cooperation and coordination for waste management.

3.4 Analytical approach and results

3.4.1 Projections for waste

An essential component of this analysis is determining the future amount of waste to be handled by Pabna. Population and waste collection data, provided by the Pabna Municipality, served as the basis for population and waste projections. Annual waste generation amounts are the product of the projected population and assumed per capita waste generation. Three projections are considered: lower, middle and upper bound based on different people and per capita generation growth rates.

3.4.2 Economic valuation

The economic valuation conducted in this study is a costs-benefits analysis comparison between the status quo landfilling waste management strategy and the alternative transformation of waste into an energy incineration strategy. All figures in Bangladesh taka are converted to US dollars following the 2014 average exchange rate of 78.80 taka per US$.

The costs and benefits parameters include both financial and environmental considerations. Financial costs include capital and operational costs, whereas environmental costs are the valuation of net emissions for each scenario. Financial benefits include revenue received through taxes and sales of electricity, while environmental benefits are the net emissions reduction for each scenario. The waste

collection cost in the landfilling scenario and transformation of waste into energy is assumed to be the same and thus are netted out of the comparison analysis. Both scenarios' economic internal rate of return (EIRR) is calculated and compared. A sensitivity analysis is conducted to determine the impact on the EIRR given some variable in the assumed parameters.

3.4.3 Landfill baseline

The landfill scenario's baseline analysis is based on financial figures listed in the 2014 Pabna Municipality budget for waste management. The budget does not itemize expenses and revenues according to the components of the waste management process, namely budget items associated with the collection, transportation, transfer and final disposal. Budget items in each category were then identified as either capital or operational expense. Capital expenses were then assigned estimates for the frequency of needed purchases. The costs per unit of waste handled ($/ton) were determined by dividing the total 2014 costs by the estimated total tonnes of waste treated by the municipal authority in 2014. These baseline costs were then projected over 20-years from 2015-to 2035 under a lower-, middle-, and upper-bound collection scenario.

3.4.4 Transformation of waste to energy

The costs and benefits of transforming waste into energy scenarios are estimated based on the data from a prior study by Hitachi Zosen (2012) for an incineration project in Greater Malang, Indonesia (see Table 2 for more details).

Table 2: Comparison of Malang region and Pabna city

Parameters of transformation of waste into energy	Malang region (Hitachi Zosen feasibility study)	Pabna City
Population	2,603,126	226,050
Population growth rate	1%	3%
Waste collection	441 tonnes/day (target in feasibility study)	395 tonnes/day (current)
Collection rate	34.7% (target)	33% (current)
Waste Moisture Content	55% – 67%, varies by season with average = 60%	Assumed to be the same
	Waste components	
Organic portion	65%	67.65%
Paper	6%	9.73%
Textiles	3%	2.50%
Wood	7%	4.20%
Plastics	16%	2.70%

Parameters of transformation of waste into energy	Malang region (Hitachi Zosen feasibility study)	Pabna City
Glass	0.6%	1.13%
Metals	0.2%	8.79%
Rubber	0.7%	2.40%
Other	1.5%	No data

Source: *Hitachi Zosen, 2012; Waste Concern, 2009; Pabna Municipality, 2015*

Parameters of transforming waste into energy adapted from the Malang study and applied in the transforming waste into energy scenario in Pabna city are summarized in Table 3.

Table 3: Transformation of waste into energy parameters of Malang WTE applied to Pabna city

Parameters of transformation of waste into energy	Malang region (Hitachi Zosen feasibility study)	Pabna City
Technical specification		
Incineration technology	Stoker grate incinerator	Same
Plant location	On landfill site	Same
Capacity of plant	800 tonnes/day	Same for lower bound scenario; varies for other scenarios
Financial specification		
Operating hours/year	8,000	Same
Investment/Capital costs	US$125 million	Same for lower bound scenario; varies for other scenarios
Interest rate on loan	6% over 20 year period	Same
Operational and maintenance costs	$35/tonne of waste	Same for lower bound; varies for other scenarios
Electricity production	7 MW (78,771,600 kWh/yr)	Same for lower bound; varies for other scenarios
Electricity consumption	152,880 kWh	Same for lower bound; varies for other scenarios
Taxes, tariffs and other considerations		
Energy from waste price	US$0.105/kWh	-
Price of emissions	US$8.50/tCO2e	US$7.20/tCO2e
GHG emissions avoided	66,874 tCO2e average/yr	61,000tCO2e avg/yr (lower bound); varies for other scenarios
Avoided landfill (savings)	US$2/tonne	US$1.93/tone
Landfill volume reduction	95%	Same

(Source: Hitachi Zosen, 2012; Waste Concern, 2009; Pabna Municipality, 2015)

Financial parameters for the 800 tonnes/day facility were adapted from Hitachi Zosen's study. Still, the estimated costs for 1,200 and 2,000 tonnes/day plant sizes are calculated from a waste technologies costs functions proposed by Tsilemou and Panagiotakopoulos (2006) following the form: $Y = \propto X^{\beta}$ (1)

where α and β constants; β < 1 and represents economies of scale; *X* is design capacity (waste to be treated annually in tonnes per year), and *Y* is the cost in Euros.

The costs and benefits, advantages and disadvantages or cost-savings

considered for transforming waste into energy in Pabna Municipality area are shown in Table 4.

Table 4: Summarization of cost-benefit of transformation of waste into energy in Pabna city

Cost	Benefit
Construction and capital Operational costs Debt service Interest paid	Waste tax Electricity sales Avoided landfilling Avoided land and capital expansion Avoided emissions

Source: *Authors' calculation, 2015*

3.5 Economic evaluation

The key assumptions that allow for the high internal rates of return are two new revenue sources for the local government: (1) per capita waste tax and (2) income from electricity sales. These revenue schemes have never been implemented in Pabna, and there is uncertainty about how accepting society will be of these new costs. Therefore, in this section, a sensitivity analysis is conducted to estimate the range of values for each of these items for the FIRR and EIRR to hold. The revised parameters and their impact on FIRR and EIRR are presented in Tables 5 and 6.

Waste tax revision: A waste tax was assumed to transform waste into energy base analysis to correct society's under-appreciation of waste services. In this analysis, the revenue from the waste tax is removed, but the tipping fee is still assumed at $38/ton, and the electricity selling price is $0.105/kWh. Only with the upper bound plant size of 2000t/d that the positive rates of return still hold. Without the waste tax levied on the public receiving waste taxes, an 800t/d and 1200t/d facility is not feasible for the local government.

Table 5: Waste tax sensitivity analysis

Revised parameter	No Waste Tax	FIRR	EIRR
Lower bound : (800t/d)	Base w/tax	0.89%	6.83%
	No tax	Unable to be determined	Unable to be determined
Middle bound: (1200t/d)	Base w/tax	15.06%	18.17%
	No tax	-1.92%	3.82%
Upper bound: (2000t/d)	Base w/tax	23.38%	25.63%
	No tax	10.89%	14.08%

Source: *Authors' calculation, 2015*

Electricity price: The assumed electricity selling price in the transformation of waste into energy base analysis is set at $0.1050/kWh, which was the feed-in tariff rate for renewable energy from waste assumed in the Hitachi Zosen for the Malang

feasibility study. But feed-in tariff system is not well established in Bangladesh. The transformation of waste into energy can ensure a feed-in tariff system.

4. Policy Implications

As shown in the analysis, the practical implementation transformation of waste into energy for Pabna is critically dependent on policy measures at both the national and local government levels. In developing countries, this uncertainty in the achievement and effectiveness of domestic policies has constrained high-cost and high-tech investments like transforming waste into energy incineration**.**

However, landfills' challenges and potential negative impact on society and the environment make ignoring the transformation of waste into energy incineration an irrational practice. The conversion of waste into energy can provide sustainable waste management and solve other challenges in Bangladesh, including the reduction of GHGs emissions and the development of renewable energy supply. It is insufficient to view waste management only in financial terms because waste management is a public good and is linked to public health and environmental amenities. A waste management project must be evaluated regarding costs and benefits to society.

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