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Municipal solid waste to energy generation: An approach for enhancing climate co-benefits in the urban areas of Bangladesh

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ABSTRACT

Ever-growing scarcity of land resources around the world brands the waste to energy (WtE) strategy as a promising option for municipal solid waste (MSW) management. WtE conversion not only reduce the land pressure problem in urban areas, but also generate electricity and heat to supply to the surrounding urban areas. Moreover it also warrants climate benefits by avoiding fossil fuel based energy. The goal of this paper is to evaluate the MSW renewable energy potential and climate benefits through carbon reduction in Bangladesh using WtE strategies for urban area waste management. The study is conducted based on the waste generation of 7 major city corporation, 308 municipalities and 208 other urban areas in Bangladesh. Energy potential of different WtE strategy is assessed using standard energy conversion model and subsequent greenhouse gases (GHG) emissions models. GHG emission avoidance is also estimated based on coal based electricity displacement and avoidance from existing MSW management practices. Six different WtE scenarios are evaluated consisting of mixed MSW incineration and landfill gas (LFG) recovery systems. The total projected GHG emission observed within the range of 3.45–4.68 million MT CO_{2eq} and 5.45–9.59 million MT CO_{2eq} by 2030 and 2050, respectively under BAU scenario. The projected highest total renewable electricity generation potential from MSW in Bangladesh observed within the range of 4173.90–5645.30 GWh by 2030, and 6582.48-11579.12 GWh by 2050. Renewable electricity potential in Dhaka is highest (1399.56-712.86 GWh) followed by Chittagong (762.74–900.24 GWh) by 2030, with associated GHG avoidance of 1.18–1.44 and 0.64–0.76 million t $CO_{2eq,}$ respectively. Scenario A_1 provides the highest economic gain with energy potential and net negative GHG emissions. The study proposes mixed MSW incineration as a potential source of renewable electricity to ensure climate friendly urban area management in Bangladesh.

1. Introduction

Around the world human society's endures race for modern urbanized life generating tremendous amount of municipal solid waste (MSW) – a key by-product of urban lifestyle. The fast urbanization rate resulting in mounting MSW generation [1,2]. A twofold increase of global MSW generation was observed for the period of 2000–2010. During 2010 global MSW generation was 1.3 billion MT and by 2025 it is projected to reach 2.2 billion MT and 4.2 billion MT by 2050 [2]. Such rapid rise of waste footprint from the urbanized system will certainly have a negative impact on sustainable living style as well as on the local environment (air, water, land) and human health, if not managed properly [3]. Rapid population growth, and the accompanied factors like fast industrialization for national economic growth, and urbanization causing severe MSW management problems in a number of cities in developing and under developed countries like China, India, Malaysia, Thailand and Bangladesh [4–7].

Significant environmental problems in Bangladesh due to improperly managed municipal solid waste (MSW) are already documented because of fast population growth and ongoing rapid industrialization [8–10]. A great influx of village workforce to cities of Bangladesh because of job availability and higher income opportunity causing tremendous expansion of urban boundary [11–13]. The two elements, i.e. population and economy growth should be constructively transformed, because they are the major drivers of sustainable waste management in Asia [5,14]. Sustainable MSW management around the world is based on four options such as- thermal treatment, biological treatment, landfilling with gas (LFG) recovery, and recycling [15]. Among them, thermal treatment, biological treatment, and LFG recovery are based on the theme of recovery, i.e., energy recovery option of MSW management hierarchy [16].

Waste-to-energy (WtE) strategy refers to any waste treatment process generating energy in the form of electricity, heat or transport fuels from a waste source. WtE is a very promising alternative energy

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Table 1
Overview of major WtE technologies.

WtE technology	Description	Conversion Efficiency (MWh/ton MSW)	Service Life (year)	Typical MSW input heating value (MJ/Kg)	Max Fuel Moisture (%)	Input	Products
Waste incineration	Mixed MSW incinerated in a boiler and equipped with CHP plant. Incineration temperatures is 1000–1200 °C.	0.5[A]	30[A]	8–10.5[B]	40–50[A]	Mixed MSW	Electricity and heat.
Pyrolysis	Thermochemical decomposition of organic fraction of MSW at low temperatures in presence of limited or in absence of oxygen. Operating temperatures is 200–300 °C.	0.3[A]	20[A]		10[A]	Sorted MSW	Liquid oil, Char, Gas
Gasification	Process of reacting the organic fraction of MSW at high temperatures with controlled amount of oxygen and steam to produce carbon monoxide, hydrogen and carbon dioxide. Operating temperatures is > 700 °C.	0.9[A]	20[A]	16.5[B]	40–50[A]	Sorted MSW	Electricity, CH_4, Hydrogen, Ethanol
Anaerobic digestion	Biological process of breakdown of organic fraction of MSW by a consortium of anaerobic microorganisms working synergistically in an oxygen poor environment. Most of the anaerobic digesters designed to operate in the temperature range of 30–35 °C.	0.15[D]	20[A]	2.5[B]	Approx. 97[A]	Sorted MSW	Electricity, heat, LNG
LFG gas recovery	Landfill gas [1] is a saturated gas consisting of 50% CH_4 and 50% CO_2 by volume, along with some other trace contaminants. CH_4 is trapped to generate electricity.	0.23[E]	30 to 50[E]	–	70–80[C]	Mixed or sorted MSW	Electricity, heat, LNG

Note: .
[A] [56].
[B] [20].
[C] [57].
[D] [58].
[E] [5].