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Review of Waste to Energy Projects in Developing Countries

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Abstract

Waste to Energy (WTE) projects have been running successfully in many countries but have produced only mixed results in developing and have often been plagued with controversies. This is due to various technical, financial, environmental, political and social factors involved. Hallam Energy at Sheffield Hallam University was commissioned by the Government of India, to conduct a detailed independent investigation into the techno-economic feasibility of such a WTE project in Delhi. The goals of this study were (i) to make an informed decision on whether the proposed WTE facility for Delhi will be technically and financially viable, and (ii) to gain a reasonable understanding of the costs and resources involved in this investment. This work looks at the various challenges associated in setting up WTE plants in developing countries and address key findings including: 1. The capacity of the plant, 2. The capital cost, 3. The electrical power output, 4. Land area requirement, 5. Site selection for the plant, 6. The choice of processes and pre-processing of the feed, 7. Feasibility of trigeneration or CHP, 8. Choice of technologies and equipment, 9. Financial models, 10. Emissions of pollutants, 11. Lessons learnt from past WTE projects in India.

Keywords: Waste to Energy (WTE), Municipal Solid Waste (MSW), Refuse Derived Fuel (RDF), Developing Countries, Trigeneration, Landfill

1. Introduction

India, the second most populated country in the world and one of the fastest growing economies, is experiencing an unprecedented growth in its industrial sector and is undergoing rapid urbanisation (Bhagat 2011, Pradhan 2017). The number of towns in India has increased by 50% from 2001 to 2011. Such growth and lifestyle transformation inevitably bring along a much augmented volume of municipal solid waste (MSW), produced from the country's recently transformed commercial, industrial and residential areas. In 2013-14, India was generating an estimated 143,449 tonnes per day of MSW at 0.11 kg/capita/day, out of which only 32% was treated or processed (MoUD, 2016). The per capita MSW generation rate for Indian cities with population above 1 million varies between 0.4-0.6 kg/day. Any disorder in handling of the

MSW generated can have catastrophic impact on India's booming economy, environment and population in future. One such accident happened on 2 September 2017 at Ghazipur landfill site in Delhi which collapsed, killing 2 people (Hindustan Timesa, 2017). Therefore, the sustainable management of the MSW is a critical concern for municipal authorities throughout the country (Hoornweg and Bhada-Tata 2012).

Most of the MSW collected in India is either burnt in open air without central collection or dumped in landfill sites. The existing landfill sites in mega cities like Delhi, Kolkata and Mumbai have dangerously exceeded their capacity already. Moreover, the traditional waste disposal technique by landfill is considered the most unfavourable route in the waste management hierarchy, as it wastes valuable land and gives rise to Green House Gases (GHG) emissions, primarily methane (Liu et al. 2017). Consequently, policies and regulations in many countries, such as the Landfill Directive in Europe, discourage landfilling and encourage recycling and resource recovery (Lukumon et al. 2013). With the drive towards circular economy gaining momentum, under current proposals, landfilling of all recyclables will be substantially reduced in the European Union (EU) in the near future (Costa et al. 2010). In India, the Ministry of Urban Development (MoUD) is seeing a long-term solution for MSW disposal in a number of large cities under Swachh Bharat Mission (MoUD 2016).

The waste incineration is seen as a conducive technique for scientific disposal of MSW that has the potential to replace landfilling of MSW. Countries such as Denmark, Japan, USA and Sweden have been leaders in using the energy generated from incineration in localised facilities supporting power generation schemes (Nakakubo et al. 2017, Lu et al. 2017). A number of other European countries rely heavily on incineration for handling municipal waste, in particular Luxembourg, Netherlands, Germany, and France. The MoUD plans to build a new state-of-the-art WTE plant in Delhi to set an example for other cities to follow. This paper aims to evaluate the feasibility of the proposed plant. It outlines the specification of the plant including the land area required, the type and quality of fuel, potential electrical outputs and capital cost requirements. Finally, it aims to identify the technical, social, political and economic challenges in the implementation of such projects and suggests solutions to overcome these challenges.

2. Size of the plant

Delhi, with a population of 19 million, currently produces circa 8,500 tonnes per day (TPD) of MSW which is expected to increase to 14,302 TPD by the year 2024 (MCD 2004). According to conservative estimates (GAIA, 2016), Delhi would require 100 km^2 of landfill area or 6.7% of the total land area in Delhi by the year 2050 if scientific methods of disposal of MSW are not implemented on a large scale. For a densely populated metropolitan city like Delhi, it would be extremely challenging to find such large land area for waste disposal. Three of the four existing landfill sites in Delhi have already far exceeded their capacity. While the permissible upper height limit for dumping garbage at a landfill is approximately 15 to 20 metres, the sites at Okhla, Ghazipur and Bhalswa are well past 40 metres (Hindustan Times[b], 2017). The Ghazipur site has now crossed 50 m. it should have been closed in 2002 but continues to receive 3,000 TPD of MSW. Apart from dumping its waste in landfills, Delhi also uses its daily waste generated in three WTE plants that can only treat maximum of 8,000 TPD combined, as compared to 8,500 TPD generated. Based on the forecast increase in MSW generation and capacity of the existing WTE plants, it was estimated that a new WTE plant would need to process at least 4,000 TPD to keep up with the demands by 2020.

3. Quality of MSW in Delhi

The electrical output of any WTE plant depends upon the composition of the MSW that is incinerated. The waste collected in Delhi contains a complex mixture from various sources – kitchen/food waste, road sweeping, drain silt, construction and demolition (C&D), industrial, etc. The composition of MSW varies in India from place to place, depending on the level of urbanisation, living standards and population density. For instance, MSW in metropolitan cities contains more packaging materials and plastics than that in small and semi-urbanised cities. The MSW, regardless of its place of origin, could contain approximately 30-40% moisture in it which is mainly due to the large quantities of kitchen and food wastes that come under biodegradable matter. Due to a lack of segregation practices at source, direct incineration of the waste would not be viable. Using raw or untreated MSW directly in the incinerator can cause incomplete combustion (or no combustion in some cases) which would ultimately result in higher emissions, energy losses and higher operating costs. Thus, the MSW should be pre-processed to separate the non-combustible and compostable or biodegradable parts. Its moisture content must be reduced and the MSW should be converted to Refuse-Derived Fuel (RDF).

In pre-processing, the moisture content is reduced to approximately 20%. The RDF produced after separation stages is rich in combustible matter, low in moisture and accounts for approximately 30-40% of the raw MSW on dry basis. On a typical day, 1,200 to 1,600 TPD of RDF will be produced in the new plant out of a feed of 4,000 tonnes of MSW. Raw MSW has a calorific value of 800-1000 kcal/kg (Lower heating value, LHV) whereas the RDF can have nearly 2,500 – 3,000 kcal/kg (LHV) depending on how efficiently the separation is carried out (Dubey 2013).

4. Electrical output from the WTE plant

The electrical output for the 4,000 TPD capacity WTE plant proposed in this report is estimated using both MSW and RDF fuels. The key outputs of the analysis are shown in Table 1. MSW being very low in calorific value and high in moisture content should not be sent directly to the incinerator. Rather, it should be converted to RDF before it is burned in the furnace. A 4,000 TPD capacity WTE plant would treat approximately 166 tonnes of MSW per hour to produce 49.9 - 66.6 tonnes of RDF per hour (which is 30-40% of MSW by mass) depending on the quality of MSW. The calorific value of the produced RDF is taken as 2,500 kcal/kg, as recommended by the Central Electricity Regulatory Commission (CERC, 2015). Table 1 indicates that processing 166.66 tonnes per hour of raw MSW (or burning 49.9 to 66.6 tonnes of RDF in the incinerator) can produce 36 - 48 MW_e of gross power output. In other words, it can be said that the plant will use 3.4 - 4.5 tonnes of MSW per hour to produce 1 MW_e of power.

Table 1: MSW treated and RDF burned per hour for 1MW_e gross power output

	Raw MSW	***RDF (@ 30% MSW)***	***RDF (@ 40% MSW)***
Fuel used per hour (kg/hr)	*166,666*	*49,998*	*66,664*
Calorific value (kcal/kg)	*800-1,000*	*2,500*	*2,500*
Thermal Energy in fuel used per hour (MW_{th}/hr)	*155.0-193.3*	*145.3*	*193.8*
Gross electricity (MW_e) @ 25% efficiency	*-*	*36.3*	*48.4*
Fuel processed/burned per hour for producing 1 MW of power ($tMW_e^{-1}hr^{-1}$)	*3.4-4.5 (processed)*	*1.37 (burned)*	*1.37 (burned)*

5. Capital requirements and cost of electricity

The CERC collected data on the existing WTE projects in India to calculate the capital cost requirements for WTE projects. The capital cost of the existing WTE plants ranges between £1 to 2.9 million per MW_e. Some of these costs also include the cost incurred in pre-processing of the MSW to produced RDF. Several other regional authorities such as Madhya Pradesh Electricity Regulatory Commission (MPERC) and Gujarat Electricity Regulatory Commission (GERC) also provided similar capital cost estimates for WTE plants.

In MSW-based WTE projects, the raw MSW used as fuel is supplied free of cost by the local municipalities. Therefore, the operation and maintenance (O&M) expenses mainly involve labour, insurance, consumables, repair and statutory expenses only, and are considered to be 5% of the capital cost with an escalation of approximately 5 to 5.72% per annum. The repair, maintenance and spares cost is 15% of the total O&M cost. On the proposed normative capital cost of £1.7 million/MW_e for MSW based projects, the proposed normative O&M expenses works out to £86,200/MW_e for the year 2015-16. The fixed cost involves O&M cost, Depreciation, Interest on Term Loan, Interest on Working Capital and Return on Equity, and it comes out to be 25 - 26% of the total capital cost. A levelised cost of electricity of £0.078/kWh has been calculated by CERC for MSW-based WTE projects.

In RDF-based WTE plants, the RDF fuel is either purchased from an external supplier or produced by the WTE plant operator at the same or a different site. The RDF, if purchased, currently costs about £20/tonne. The fixed O&M cost for an RDF-based WTE plant is the same as that for MSW-based plant, i.e. 5% with an escalation of 5.72%. On the proposed normative capital cost of £1.03 million/MW_e for RDF based projects, the proposed normative O&M expenses works out to £51,700/MW_e for the year 2015-16. The fixed cost per annum for RDF projects is approximately 27.5 - 28.5% of the total capital cost. A levelised cost of electricity of £0.0106/kWh was estimated by CERC for RDF-based WTE projects.

6. Funding model for the project

BOOT (build, own, operate, transfer) is a public-private partnership (PPP) project model in which a private organisation conducts a large development project under contract to a public-sector partner, such as a government agency. A BOOT project is often seen as a way to develop large public infrastructure projects with private funding. Most of WTE projects in India have been based on this BOOT model and have been running successfully. It is thus the only proven financial model for such WTE projects in developing countries like India.

7. Key issues and mitigating factors

The WTE in India is perceived as "wealth from waste" since such projects had run successfully in many developed countries (The Economic Times, 2018). Articles published in newspapers described WTE as a gold mine (World Economic Forum, 2017). Such statements caused many businesses and investors in India to rush into the WTE business without full knowledge of the reality and key local factors. The first WTE plant in India was setup in 1987 at Timarpur, Delhi which failed primarily because of poor quality of MSW used as fuel in the plant (GAIA 2016, Dhamija 2013). Since then, the WTE projects have produced mixed results in India (Joshi and Ahmed, 2016). There are no proven examples of successful WTE projects in India and the initial plants faced many failures. The critical factors of failure and mitigating factors of WTE projects in India are summarise in Table 2.

Table 2: A summary of the causes of failures/pitfalls for WTE project in India and their possible mitigating factors.

Cause of Failure/Pitfalls	Cause	Possible Mitigating Solutions
Omitting pre-processing MSW before incineration	Technical	• Sorting of waste to remove non-combustible components • Pre-processing to produce RDF as the fuel

Underestimated electrical tariffs by bidders	Economic	• Minimum tariff recommended by the CERC should be agreed to allow for effluent treatment and viability • Tariff for tri-generation can certainly supplement the revenues for the operator • Offer gate-fees for receiving the waste at the plant
Defective tendering system – based on lowest electricity unit price only	Economic	• Careful screening of bids for financial viability • Consider WTE plants as primarily waste management sites and not power plants
Abuse of government grants	Policy	• Revoke up-front government grants • Offer performance/output-based grants to encourage operation and support genuine bidders/operators
Arbitrary and unpredictable one-sided changes from regulators, e.g. stricter emission limits	Policy	• Contract should allow a revision of tariff for electricity if emission limits are changed after the plant is built. • Else, the government should offer a grant or subsidy to support the operator • Plants should be designed from start to comply with the EC Waste Incineration Directive which imposes the strictest emission limits
Fluctuations in carbon credit prices	Economic	• Financial model should not include revenues from volatile streams like carbon credits but on steady and reliable outputs like power, hot water and cooling
NIMBY syndrome and public propaganda	Social	• Early public engagement • Use of an industrial land for the plant site • CSR fund could be used to build a visitor centre and invite public to learn about the MSW processing and its environmental benefits
Conflicts of interests	Social	• Careful planning, dumping legislation and monitoring of the operator and contractors.

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