Sustainable Energy Technologies and Assessments 21 (2017) 23–32

Contents lists available at ScienceDirect

Sustainable Energy Technologies and Assessments

journal homepage: www.elsevier.com/locate/seta

Original article

Energy recovery from waste in India: An evidence-based analysis

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ARTICLE INFO

Article history:
Received 25 November 2016
Revised 13 February 2017
Accepted 18 April 2017

Keywords:
Waste-to-Energy (WtE)
Municipal Solid Waste (MSW)
Energy-from-Waste (EfW)
Energy policy
Waste management

ABSTRACT

The uptake of Waste-to-Energy (WtE) in India has not been successful and the majority of plants have failed to sustain operations. There is a lack of detailed on-the-ground research examining the causes of plant failures and the issues regarding the WtE supply chain. Thus, this study set out to identify how WtE practices in India can be improved by gathering and evaluating empirical evidence. Local government officers, industry practitioners and academics involved in waste management in India were consulted. Quantitative data were collected on three case study plants: an incinerator, a gasification plant and a plant co-firing waste with coal. The gathered information was evaluated by making a comparison with two European waste incinerators. The major problem with WtE in India has typically been perceived to be poor source segregation; however, the case study plants highlight that severe contamination has been occurring during transport and storage. In comparison to the European incinerators, the WtE plants in India had a low capital cost (around 1–2 million €/MW), but total particulate matter emissions were a hundred times higher, ranging from 65 to 75 mg/Nm^3. We conclude with recommendations for delivery contracts, financial incentives and regulations on dumpsites, ash disposal and stack emission measurements.

Introduction

In India, around 40 million tonnes of urban Municipal Solid Waste (MSW) is produced every year, and the majority of this waste is sent to unsanitary landfill sites or openly dumped [1,2]. Although attempts to improve MSW management in India have been made (e.g. the introduction of the MSW Management and Handling Rules 2000 and Solid Waste Management (SWM) Rules 2016), many Indian cities are still unable to comply with regulations, and the situation is being exacerbated by rapid urbanisation and population growth. The composition of India's MSW is highly variable among urban and rural areas; however, it is typically characterised by a high percentage of organic and inert content. As rag pickers collect recyclable materials from the disposed MSW, the percentage of paper, plastic, glass and metal is often low [3].

One area of growing interest in India is energy recovery from MSW, as it can provide valuable energy services, reduce waste volume and alleviate some of the health and safety hazards associated with current waste management practices. The World Energy Council [4] reported that the Asia-Pacific region is the fastest growing market (in terms of market size) for Waste-to-Energy (WtE) and that this is due to developments in China and India. The recent growth in these countries has been spurred by an improved awareness of the hazards and environmental impacts associated with MSW and increasing energy and land requirements [5]. The Government of India [6] state that non-recyclable waste with a calorific value of 1500 kcal/kg must be used for energy recovery or in the preparation of refuse-derived fuel (RDF). It has been estimated that the potential for MSW to energy in India is as high as 1.5 GW and only 2% of this total has been realised [7]. In urban areas of India, the land required for landfill is approximately 1240 hectares per year and the majority of dumpsites are over their capacity. As of 2012, only eight WtE plants have ever been installed in India, along with 279 compost, 172 anaerobic digestion and 29 refuse-derived fuel plants [8].

A number of large-scale projects for composting, biomethanation, RDF and WtE have failed in India. Previous attempts at utilising RDF include a 6.6 MW plant in Hyderabad, 6 MW plant in Vijayawada and 500 tonnes per day (tpd) plant in Chandigarh [9]. In 1987, a 3.7 MW WtE plant processing 300 tpd was set up by Mijotecknik in Timarpur, New Delhi; however, it was forced to close within 6 months due to the MSW feedstock having a low calorific value (550–850 kcal/kg) and high moisture and inert

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http://dx.doi.org/10.1016/j.seta.2017.04.003
2213-1388/

content [10]. Plants incinerating MSW in other developing countries have faced similar problems and been discontinued [11]. Small-scale biomethanation plants have in general been more successful in India. As of the time of writing, only one WtE plant incinerating just MSW remains in operation in India. Whilst, incineration and gasification have been considered to be more promising than RDF for the thermochemical disposal of MSW in India [12], integrated material recovery facilities, composting, incineration and landfilling would likely provide the greatest environmental benefits [13].

The WtE industry in developed countries is well-established in comparison to India. Even though issues still exist in developed countries (public opposition, expensive flue gas treatment measurements, disposal of air pollution control residues, and fouling and corrosion of boiler heat exchanger surfaces), the most suitable technologies and processes for treating waste are well-known [14–16]. However, the issues facing the WtE industry in India are multifarious and many of these issues differ from those encountered in other countries due to different cultural practices and economic climates. Moreover, issues encompassing policy uncertainties, economic barriers, technical difficulties and logistical challenges in India are still not clearly defined or understood.

Several authors have evaluated waste-to-energy practices in India to draw conclusions on the causes of WtE failures. Kalyani and Pandey [9] suggested that MSW plant closures have been due to a lack of logistical planning and financing. Chattopadhyay et al. [17] asserted that the major problem with MSW in Kolkata was poor waste segregation, collection efficiencies and recycling systems. They claimed that the incineration of MSW was not suitable in Kolkata due to the low energy content of MSW (3350–4200 kJ/kg) and reported that a tipping fee in the region of 3900–5200 Rs./tonne would be required to make WtE financial viable. Srivastava et al. [18] carried out a strengths, weaknesses, opportunities and treats (SWOT) analysis of MSW management in India and gathered stakeholder opinions from government ministries, research institutions and community representatives in Lucknow. They concluded that the weaknesses of MSW management in India were a lack of facilities, adequate transportation and expertise in government. Singh et al. [19] outlined the potential for energy recovery from MSW using various technologies in India and detailed some of the operating plants in India. However, the challenges that these plants faced were not addressed. A comparison of the broader range of different disposal options for waste in India can be found in Ref. [20].

Researchers have typically had to rely on using secondary data to evaluate WtE practices in India. Similarly, authors carrying out research on WtE in other developing countries have focused on reviewing the literature to provide an overview and discussion of the various challenges [21–24]. Guerrero et al. [25] conducted a review of waste management in developing countries and claimed that there was a lack of quantitative data. They suggested that there was a need for research to identify the most critical issues by observing urban areas and surveying a range of stakeholders. Where stakeholder opinions on WtE in India have been gathered before, there has been a tendency to focus on municipalities and not include the industry's perspective [18]. To the authors' knowledge, there is no study using primary data to make a detailed comparison of WtE plants in India. Furthermore, industrial stakeholder opinions on the issues of WtE in India have not been gathered alongside those of local governments and academics.

As India continues to develop, a significant amount of investment will be made in alternative WtE facilities. Therefore, there is a need for research to use primary data to characterise and identify the issues that have prevented or will prevent the successful deployment and operation of viable energy recovery facilities. This study aims to address this need by working closely with industries and local governments to provide answers to the following specific research questions:

i. What do industry and government stakeholders perceive the major issues and challenges to be regarding the successful uptake of WtE plants in India?
ii. How do the operations and performance of WtE plants in India compare with established plants in other countries?
iii. What improvements need to be made in order for WtE to become a viable method for energy generation and municipal solid waste management in India?

The answers to these questions will direct future research and development efforts, and address the gap in the primary data available in the literature. Furthermore, the study's findings will guide and inform strategic decision making across the entire supply chain, i.e. from energy policymaking and planning to plant operation. The methodology that has been adopted to achieve this study's goals is outlined in the following section. In Section "Workshop results", details of a workshop held with Indian stakeholders are outlined, and in Section "Case study comparison" three case study plants are analysed. The study concludes by providing recommendations to make WtE more sustainable in India.

Methodology

This empirical study set out to address the first research question by surveying a range of stakeholders from across the WtE supply chain. A workshop was conducted to bring together stakeholders from across India and served as an opportunity for a group of stakeholders to discuss and define the general issues and challenges with implementing WtE initiatives in India. The participants included 26 officers from Urban Local Bodies (ULBs), 20 industry practitioners and 6 Indian academics to provide a neutral perspective and represent members of the community with expertise in WtE (details of the participating originations can be found in Appendix A of the Supplementary Online Material). The workshop session was carried out in two phases: i) distribution of a survey asking individual stakeholders to provide their opinions on the issues and challenges with WtE in India, cause and effects of these issues and possible solutions and, ii) a group discussion followed by small breakout sessions to capture detailed qualitative information regarding the survey responses. During the discussion sessions, the authors acted as observers to record and categorise the types of issues raised into logistical, technical, financial, social and political. To narrow the focus of the survey, the participants were limited to raising three issues. The results were summarised by recording the number of times a similar issue was identified and reviewing the survey results alongside the information gathered during the discussion sessions.

Whilst it cannot be assumed that the 52 workshop participants fully represented the opinions of WtE stakeholder across the whole of India, they were considered to provide a reliable overview given that they represented a broad range of different industries and municipalities. Thus, it is assumed that a different make-up of the panel would have provided similar results. Moreover, the limited panel size stimulated participation and contribution. An improvement to future studies would be to include more selected representatives of the public.

To detail the specific on-the-ground issues faced by operational energy recovery from waste plants in India, three case study plants were identified and subsequently examined (a conventional MSW incinerator, an RDF gasification plant and a co-firing plant using MSW and RDF). These plants were chosen as they represented the different thermochemical treatment options currently being