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Assessment of environmental and economic performance of Waste-to-Energy facilities in Thai cities

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ABSTRACT

Waste-to-Energy (WtE) technologies seem to be an option to tackle the growing waste management problems in developing Asia. This paper presents a quantitative assessment of the environmental and economic attributes of two major WtE technologies: landfill gas to energy (LFG-to-energy) and incineration in Thai cities. Net greenhouse gas (GHG) emissions, net fossil resource consumption and net life-cycle cost (LCC) were used as the basic indicators for measuring performance of these two technologies from a life cycle perspective. The assessment found that at the current efficiency level, both the LFG-to-energy project and the incineration facility contribute to GHG mitigation and fossil resource savings as compared to the Business as Usual (BAU) practice. However, the financial returns from these operations are very low and insufficient to compensate the costs. The paper argues that substantial improvements of WtE plants can be made by adopting proper management practices, enhancing the efficiencies of energy production. Such upgrading would further reduce GHG emissions, increase fossil resource savings and strengthen the financial performance to the benefit of local governments. The authors recognize the potential of incorporating other treatment options along with WtE technologies, for moving towards more sustainable waste management approaches like integrated waste management systems.

1. Introduction

Rapidly growing populations have accelerated the generation rate of Municipal Solid Waste (MSW) in cities, causing this issue to become more and more crucial both for the daily management and long term sustainability of cities. The urbanisation of the world's population is set to continue: by 2025 the world's population is projected to be about 8 billion, of which nearly 5 billion will live in urban areas. By 2015, there will be 33 mega-cities in the world, and 27 of them will be located in the developing world especially in South-East-Asia [1,2]. At present, MSW generation in Asia surpasses 1 million tonnes/day, and it is estimated that in 2025, this figure will increase to 1.8 million tonnes/day [3].

Most of the cities in developing Asia are practicing open dumping and partly controlled landfilling without gas recovery. These simple disposal methods have well-documented adverse impacts on climate change, human health and the environment and there is general agreement that improvements are needed [4,5]. In addition, space for landfill construction is limited in and around cities. Waste therefore often has to be transported long distances out of the urban area which requires additional resources and increases operation costs [6].

Climate change is a global issue of increasing importance and urgency, thus leading cities in developing Asia need to plan climate-abating waste management plans [7]. Energy recovery from waste could be an option for greenhouse gas (GHG) mitigation as this energy would meet some of the increasing energy demands in cities while minimising long-distance waste hauling that consumes a great deal of energy. Therefore, it would appear that developing cities in Asia are strong candidates for refining renewable energy from waste streams as this would contribute to gradually replacing traditional petroleum refineries [8]. There is a fast-growing trend in Asia to move towards properly designed and managed sanitary landfills with gas recovery systems since such projects both provide an opportunity to generate renewable energy and opportunities to receive financial support through carbon financing [9]. In addition, some developing Asian cities are interested in waste incineration, which reduces waste mass by 75% and volume by up to 90%, as a solution to the acute lack of landfill sites.

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The prospects of improving sanitary conditions combined with the expected financial benefits from energy recovery add further to this interest [10,11]. Incineration would directly eliminate methane emissions from anaerobic degradation of waste at landfill sites and could also displace some fossil fuel-based electricity generation. Due to all these reasons, there is growing interest in the application of these technologies as a near-term solution to the growing waste management challenges in developing Asia.

In general, the application of WtE technologies which are well-designed to suit the local situation would contribute to GHG mitigation, energy recovery and reducing health risks. Efficiency of energy recovery would strongly effect the significance of achieving the environmental and economic co-benefits [12]. However, inefficiencies are a common obstacle in most of the cases of failure in developing Asia [9,13]. For instance, there is a high possibility of failure if these technologies are implemented in developing countries without proper adaptation to local conditions since these are designed mostly for the situation in developed countries. Further, these technologies are relatively expensive treatment options in waste management due to high capital investment and high operating and maintenance costs. Therefore, the design phase of any kind of WtE project is very important for careful selection and adaptation of technologies which best suit the local conditions. This study assessed the environmental and economic performance (GHG emissions, fossil energy consumption/savings and financial returns to local entities) of two WtE technologies based on data from currently operating facilities in Thailand. Further, possible improvements have been suggested for enhancing the efficiency of WtE technologies for improving environmental and economic benefits. The research findings would be beneficial to all levels of stakeholders in waste management for understanding the common issues of WtE technologies in developing Asia and also for identifying opportunities for strengthening the financial returns and environmental benefits. It should be noted that the toxicological effects of pollutants emitted from incineration has been the subject of much debate in many countries. Therefore, such toxicological effects and the potential for implementing efficient pollution control devices should be a topic for future studies.

2. Methodology

The evaluation of existing WtE technologies from an environmental and economic perspective via a life cycle approach is an important step for upgrading the existing technologies as well as for making sound decisions at the design phase of the new systems. This study was done to evaluate the environmental and economic attributes of two major WtE technologies in Thailand. Rachatewa landfill, located in the Bangkok Metropolitan Area (BMA), was evaluated to understand the common environmental and economic attributes of sanitary landfill with a gas recovery system in cities. There is no functioning incineration plant in BMA and, therefore, the Phuket plant (the biggest incineration plant in Thailand) was assessed in order to understand the common pros and cons of this technology in the Asian context.

2.1. Selection of the study locations and description of the existing WtE systems

2.1.1. Sanitary landfill with gas recovery in BMA

Bangkok is one of the megacities in developing Asia which is faced with the urgency of taking the right action and adopting the right technology for tackling the growing waste management problem. In Thailand, more than 20% of MSW is generated in BMA [14]. In the year 2011, the waste generated in BMA amounted to 8700 tonnes/day. The Jaroensompong Corporation initiated a landfill gas recovery project at the Rachathewa sanitary landfill site in BMA, which is the first CDM project to utilise LFG for electricity generation on a commercial basis in Thailand [15]. The Rachathewa sanitary landfill site was constructed in 1999. The total area of the landfill site (site I and site II) is 40 ha and the height of the landfill is 18 m. The existing LFG recovery project was initiated using site I which is 8 ha in size. The total amount of accumulated waste was 4.7 million tonnes, consisting of 2.5 million tonnes of newly disposed waste and 2.2 million tonnes of old waste moved from the former neighbouring landfill site when that site was shut down in 2001. During the active phase of the Rachathewa sanitary landfill site (1999–2001), the MSW disposal rate was 3500 tonnes/day. The average composition of the disposed MSW consisted of food waste (40.89%), yard waste (14.20%), plastics (25.03%), paper (15.58%), glass (1.82%), metal (0.21%) rubber and leather (0.68%), and other waste (0.65%) [16,17].

This landfill has been designed to maintain sanitary conditions. This includes a composite liner system, leachate collection and treatment system and an LFG recovery system. Recovered LFG is utilised as a fuel source for running a 1 MW generator to produce electricity with 45.5% efficiency. The excess amount of extracted LFG is flared. The LFG recovery and crediting period has been limited to 10 years with the project commencing in 2008 and intended to continue until 2017. The electricity production capacity has been limited to 31.3 kWh per tonne of waste disposed. 10% of the electricity produced is utilised for operational activities at the landfill site and the remaining 90% is sold to the grid.

2.1.2. Incineration plant in Phuket

Most of the cities in Asia have strong interest in the application of waste incineration as a solution to the problem of reducing the volume of waste. This is because there is insufficient land area available to dispose of waste and also this could contribute to generating renewable energy in the city. The biggest existing incineration plant in Thailand is located on Phuket Island. The designed capacity of the existing incineration plant is 2.5 MW and this plant was installed in 1999. The expected life time of this incineration plant is 20 years and it manages more than 50% of the waste generated in Phuket. At the moment, 300 tonnes of collected waste is sent to the incineration plant. Similar to most of the developing Asian cities, waste separation is not practiced in Phuket and mix waste is being used at the incineration plant. The average composition of waste combusted in the Phuket incineration plant consists of food waste (23.5%), yard waste (11.2%), plastics (19.0%), paper (25.7%), rubber and leather (5.0%), textile (2.1%) and incombustibles (13.6%).

The received waste has very high moisture content and it is stored in a waste pit for 4–5 days in order to remove the moisture. Within this period 50 tonnes of moisture is drained from the moist waste, and the remaining 250 tonnes of waste is used for the incineration process. The moisture content of the combusted waste is 40–42%. The high moisture content of the mixed waste has an influence on reducing the efficiency of the incineration plant and the electricity generation capacity. The average electricity production potential in the Phuket incineration plant amounts to 144 kWh per tonne of combusted waste (which is equal to 120 kWh/tonne of collected waste, see Fig. 1). Plant operation activities require 60% of the electricity produced with the remaining 57.6 kWh/tonne of combusted waste (48 kWh/tonne of collected waste) being sold to the grid. Residue waste (200 kg per tonne of waste) from incineration (ash and non-combustibles) is being disposed in a sanitary landfill next to the incineration facility. Several techniques has been employed for pollution control. Calcium hydroxide or lime is used to absorb the SO_2 and HCl. Temperature is maintained 800–1000 °C to control the formation of NO_x and dioxine. Furthermore, activated