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A financial feasibility model of gasification and anaerobic digestion waste-to-energy (WTE) plants in Saudi Arabia

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ABSTRACT

Municipal Solid Waste (MSW) generation in Saudi Arabia is increasingly growing at a fast rate, as it hurtles towards ever increasing urban development coupled with rapid developments and expanding population. Saudi Arabia's energy demands are also rising at a faster rate. Therefore, the importance of an integrated waste management system in Saudi Arabia is increasingly rising and introducing Waste to Energy (WTE) facilities is becoming an absolute necessity. This paper analyzes the current situation of MSW management in Saudi Arabia and proposes a financial model to assess the viability of WTE investments in Saudi Arabia in order to address its waste management challenges and meet its forecasted energy demands. The research develops a financial model to investigate the financial viability of WTE plants utilizing gasification and Anaerobic Digestion (AD) conversion technologies. The financial model provides a cost estimate of establishing both gasification and anaerobic digestion WTE plants in Saudi Arabia through a set of financial indicators, i.e. net present value (NPV), internal rate of return (IRR), modified internal rate of return (MIRR), profitability index (PI), payback period, discounted payback period, Levelized Cost of Electricity (LCOE) and Levelized Cost of Waste (LCOW). Finally, the analysis of the financial model reveals the main affecting factors of the gasification plants investment decision, namely: facility generation capacity, generated electricity revenue, and the capacity factor. Similarly, the paper also identifies facility waste capacity and the capacity factor as the main affecting factors on the AD plants' investment decision.

1. Introduction

By the end of 2012, the world generated more than 1.3 billion tons of Municipal Solid Waste (MSW) annually. This alarming rate of MSW generation is forecasted to reach 2.2 billion tons by the end of 2025 (Hoornweg and Bhada-Tata, 2012). In its report "What a Waste", the World Bank (2012) cited the global high urbanization levels as one of the main causes of the high rate of MSW generation as urban residents generate twice as much waste as rural residents. Furthermore, the average rate of MSW generation was 0.64 kg/capita/day in 2002. This rate of MSW generation has experienced a significant surge in the subsequent years reaching a rate of 1.2 kg/capita/day in 2012 and is even projected to keep rising to a rate of 1.24 kg/capita/day of MSW by 2025 as the levels of global urbanization are expected to increase at a much higher rate, hence, the importance of establishing resilient waste management practices (Hoornweg and Bhada-Tata, 2012).

Waste management was originally adopted for the purposes of waste volume reduction and maintaining high levels of public hygiene. However, over the years, waste management concept has evolved to include the concepts of waste prevention, waste recycling and WTE. Waste management, nowadays, encompass wide range of objectives, e.g. environmental protection, resources conversion and energy generation (Brunner and Rechberger, 2015). However, almost three quarters of the global MSW are disposed of in landfills and dump sites while the remaining quarter is recycled or utilized in WTE plants to generate heat or electricity (Gasification Technologies Council, 2011). Landfills accounts for the highest proportion of the MSW composition globally, greatly contribute to the greenhouse gas (GHG) emissions which are considered to be the main cause of climate change, therefore, addressing the global MSW challenges contribute to the overall global efforts of combating climate change through reducing environmental pollution and WTE plants present a sustainable solution to the global MSW challenges (Cucchiella et al., 2014).

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Developing Asian countries, in general, are facing a huge MSW management challenges due to their high population levels. WTE technologies present a unique opportunity to countries like India, Sri Lanka and Bangladesh to address their MSW challenges and meet their energy demands simultaneously (Dasanayaka and Wedawatta, 2015; Shariar and Al-Bustam, 2012; Rathi, 2006.). This also includes Malaysia which disposes 28,500 tons of MSW directly into landfills daily (Agamuthu and Fauziah, 2011; Fauziah and Agamuthu, 2012). However, strong Asian economies like Japan and South Korea reached advanced levels of sustainable solid wastes that includes "Zero Waste" and/or "Zero Landfilling" which is certainly expensive for weaker economies such as those of India or Indonesia (Shekdar, 2009). Between 1997 and 2002, Taiwan succeeded to reduce total MSW production by 27%, where the average daily per capita weight of MSW had fallen from 1.14 kg in 1997 to 0.81 kg in 2002 (Lu et al., 2006). In China, Li et al. (2013) stated that, by 2010, about 60% of the overall solid waste generation in China had already been reutilised, and more than 20% of the total resource requirement was reutilised resource.

Although Saudi Arabia has the largest oil reserves in the world, it has recently stepped up its efforts to shift its energy focus towards renewable energy. Saudi Arabia has a vested interest in adapting waste to energy technologies, renewable sources of clean energy, in order to address its waste management challenges. Saudi Arabia's energy demands has also risen at an average rate of 5% annually, faster than some of the world's biggest emerging economies, such as, China, and India. Currently, Saudi Arabia is the seventh largest energy consumer worldwide (International Renewable Energy Agency, 2016). Alhumoud et al. (2004) studied the financial feasibility of a national recycling program in the Gulf Co-operation Council (GCC), in general, and in Saudi Arabia in particular. Ouda et al. (2013) assessed the potential contribution to the electricity demand up to 2032 in Saudi Arabia for an incineration WTE with recycling and without recycling facilities. The WTE incineration plant has the potential to produce almost 166 MW for the recycling scenario and about 2073 MW without the recycling scenario. Hakami and Abu Seif (2015) suggested that the public themselves must be socially involved in pre-sorting their MSW. Khan and Kaneesamkandi (2013) attempted to study the environmental benefits and the financial feasibility of anaerobic digestion WTE plant. According to the study, an anaerobic digestion WTE facility in Saudi Arabia with a waste processing capacity of 21,112 (ton/day) would generate electricity at a rate of 398.528 (KWh/ton) and has a total cost of about 12 million SAR (USD 3,199,062).

Waste to Energy (WTE) plants presents a unique opportunity for Saudi Arabia to address its waste management challenges, and meet its energy obligations. More importantly, it offers Saudi Arabia the opportunity to contribute to the global green efforts of combating climate change. WTE technologies are waste treatment processes that convert the energy content of different types of waste, mainly MSW, into either power, i.e. electricity, or heat (Rogoff and Screve, 2011). Furthermore, WTE technologies are classified into two main categories: Thermochemical conversion technologies, i.e. incineration, gasification, pyrolysis, etc., and Non-thermochemical conversion technologies, i.e. anaerobic digestion (AD), fermentation, composting, etc. (Rogoff and Screve, 2011). However, this research focuses on generating electricity by utilizing gasification and AD conversion technologies, which are considered to be the most optimal conversion technologies in terms of their capital cost, electrical generation efficiency (Gasification Technologies Council, 2011), environmental benefits (Purser, 2011) and their effects on potential recycling initiatives (Gasification Technologies Council, 2011).

The objective of this paper is to analyze the current situation of MSW management in Saudi Arabia and propose a financial model to assess the viability of WTE investments in Saudi Arabia. The developed financial model investigates the key affecting investment factors to justify establishing WTE plants based on the gasification or the AD conversion technologies. The financial analysis is based on a set of financial indicators, i.e. net present value (NPV), internal rate of return (IRR), modified internal rate of return (MIRR), profitability index (PI), payback period, discounted payback period, levelized cost of electricity (LCOE) and levelized cost of waste (LCOW). The data and the finical figures in this research are collected and gathered as a result of an extensive review of local and international published researches, reports and studies that were conducted by academic institutions, governments' entities, independent agencies as well as reputable expert individuals. Finally, sensitivity analysis is conducted on the developed financial model to identify the key affecting factors that the decision makers should pay more attention towards.

Nomenclature of abbreviations	
GCC	The Gulf Co-operation Council
BFB	Bubble Fluidized Bed
CAPEX	Capital Expenditure
WACC	Weighted Average Cost of Capital
GHG	Greenhouse Gas
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
MOMRA	Ministry of Municipal and Rural Affairs
KACARE	King Abdullah City for Atomic and Renewable Energy
NPV	Net Present Value
OPEX	Operation and Maintenance Expenditure
PI	Profitability Index
RDF	Refuse Derived Fuel

2. Materials and methods

The data and the finical figures in this research are collected and gathered as a result of an extensive review of local and international published researches, reports and studies that were conducted by academic institutions, governments' entities, independent agencies as well as reputable expert individuals.

The International Renewable Energy Agency (IRENA), a renowned international organization that specializes in renewable energy researches, in its report titled "Renewable Power Generation Costs" (2015) presented a set of globally applicable financial costs related to the cost of establishing gasification and anaerobic digestion WTE plants after investigating a set of financial information derived from already existing plants worldwide to assess the financial performance of these types of WTE plants (International Renewable Energy Agency, 2015). According to IRENA (2012), the choice of the type of the gasification or the anaerobic digestion WTE technology is greatly dependent upon the cost, the type and the availability of the waste utilized by the gasification or the AD conversion system. Furthermore, it also relies on the local demands for energy, i.e. electricity and heat (International Renewable Energy Agency, 2012). To better understand the economic needs for the WTE projects, the literature related to MSW in Saudi Arabia and international best practices are collected and evaluated which further helped to estimate the input parameters to develop the financial model. Finally, it enabled to perform the sensitivity analysis (study the effect of input parameters on the financial indicators) as described in Canada et al. (2005). The main steps of this approach are: MSW analysis in Saudi Arabia, financial model development, and sensitivity analysis.