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Waste to energy potential: A case study of Saudi Arabia

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ABSTRACT

This paper reviews the global status of waste to energy (WTE) technologies as a mean for renewable energy production and municipal solid waste (MSW) disposal method. A case study of the Kingdom of Saudi Arabia (KSA) under this concept was developed. The WTE opportunities in the KSA is undertaken in the context of two scenarios: (1) incineration and (2) refuse derived fuel (RDF) along with biomethanation from 2012 to 2035. Biomethanation technology can proved to be the most suitable WTE technology for KSA due to (a) availability of high food waste volume (37% of total MSW) that can be used as a feedstock, (b) higher efficiency (25–30%) and (c) lowest annual capital ($0.1–0.14/ton) and operational cost. However, the need for large space for continuous operation might increase operational cost. The RDF has an advantage over incineration due to (a) less annual capital ($7.5–11.3/ton) and (b) operational cost ($0.3–0.55/ton), but the high labor skills requirements will most probably be a limitation, if appropriate training and related infrastructure are not scheduled to be included as a prerequisite. The incineration technology also proves to be an efficient solution with a relatively higher efficiency (25%) and lower operational cost ($1.5–2.5/ton). However, the need for treatment of air and waterborne pollutants and ash within the incineration facility can be the limiting factors for the development of this technology in KSA. In 2012, the power generation potential for KSA was estimated at 671 MW and 319.4 MW from incineration and RDF with biomethanation scenarios respectively, which was forecasted to reach upto 1447 MW and 699.76 MW for both scenarios respectively by 2035. Therefore, WTE technologies, could make a substantial contribution to the renewable energy production in KSA as well as alleviating the cost of landfilling and its associated environmental impacts. However, the decision to select between the two scenarios requires further in-depth financial, technical and environmental analysis using life cycle assessment (LCA) tool.

Contents

Abbreviations: CAGR, compound annual growth rate; CH_4, methane; CO_2, carbon dioxide; CO, carbon monoxide; GHG, greenhouse gases; H_2, hydrogen; KACARE, King Abdullah City of Atomic and Renewable Energy; KSA, Kingdom of Saudi Arabia; LCA, life cycle assessment; LFG, landfill gas; LHV, low heating value; MSW, municipal solid waste; NCV, net calorific value; N_2, nitrogen; O_2, oxygen; RDF, refused derived fuel; SSO, source separated organic; SWM, solid waste management; VAP, value-added products; WTE, waste-to-energy

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1. Introduction

World population is projected to reach 8.2 billion in 2025 with current annual growth rate of 1% [1]. The major population growth will occur in the developing countries, with more than half of it only in Africa [2]. About half of the world's population is currently either living or moving towards urban areas at a higher rate (1.5%) than the population growth [2]. Urbanization in developing countries, especially in Asia, will be higher due to intensified industrialization [3]. Therefore, it can be concluded that increase in energy consumption and waste generation will occur worldwide (Figs. 1 and 2). Similarly, the world's energy demand is expected to increase up to 58% by 2025 in comparison to current demand (46%) [6]. In Asia, for example, the energy demand is estimated to increase at an annual rate of 3.7% [7] that will transform this region into an area of high interest for future energy developments.

At present, fossil fuels are the most relied source of energy supply worldwide [7]. Coal, crude oil, and natural gas are used to produce 13,700 TWh of electricity that is approximately 84% of the global electricity production (Fig. 3). They are causing serious environmental pollution, especially generation of greenhouse gases (GHG) and climate change. Therefore, renewable energy sources have gained more attention in the last two decades [8]. The technological advancement, process-cost reduction, and governmental incentives have made renewable energy sector including waste to energy (WTE) more competitive in the energy market [9]. WTE is a viable option for both municipal solid waste (MSW) disposal and renewable energy production. Current global MSW generation level is 2.4 billion tons per year that is projected to reach upto 2.6 billion tons per year by 2025 [4]. Therefore, the appropriate treatment of MSW that secures their sustainable contribution to increasing energy demands is essential [10].

The Kingdom of Saudi Arabia (KSA) is one of the world's largest energy consuming country due to ever increasing population, urbanization and living standards [11]. In 2013, the country was among 12 largest primary energy consumer countries of the world with total energy consumption of 9 quadrillion British thermal units (Btu) [5]. The current peak demand of electricity is around 55 GW that is estimated to double (120 GW) by 2032 [12]. Fossil fuels are the only source to meet the energy requirements of the country; petroleum cover around 55% and natural gas fulfill around 45% of KSA's energy needs [13]. The KSA government is ambitious to generate about 72 GW energy from renewable sources such as nuclear, solar, wind, geothermal and WTE by 2032 [12–14].

In KSA, 15.3 million tons of MSW was produced during 2014 with an average rate of 1.4 kg/capita/day. This amount is estimated to double by 2033 [11]. The collected MSW is disposed to landfills or dumpsites, after partial recycling of paper and cardboard that is 10–15% of total MSW [13]. The current land-area demand for making new landfills is extremely high (upto 2.8 million m^2/year) [8,12]. The waste management practices are causing environmental and public health problems [13]. Therefore, the KSA Government is seeking sustainable solutions for MSW management, including its treatment and energy recovery as a mean to bridge the ever increasing energy demand–supply gap [12].

In KSA, neither such WTE facility exists to convert MSW into energy, nor is the potential of MSW examined as an energy source [4]. Therefore, this study will add a significant value to sustainable waste management strategies and renewable energy production for KSA [11]. This paper examines the potential of power generation from 2012 up to 2035 using WTE technologies for the KSA. Two scenarios were applied namely incineration and refuse

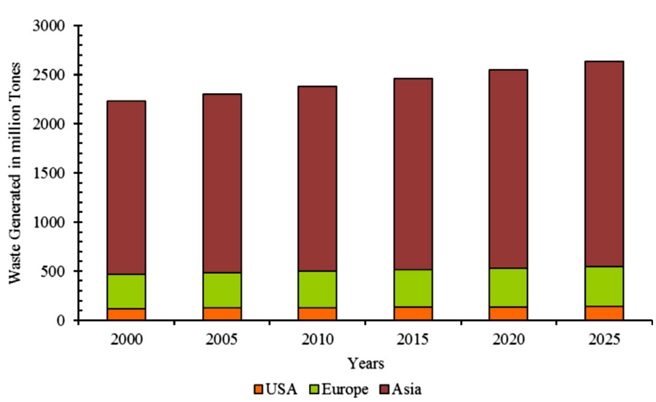

Fig. 1. Municipal solid waste generated in million ton/year in Asia, Europe and USA for the 2000–2025 period [4]. The forecast was developed by assuming an average MSW generation of about 1.3 kg/capita/year globally.

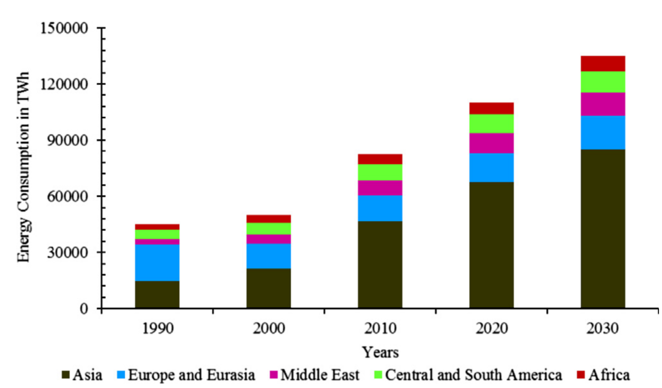

Fig. 2. Energy consumption in TWh for Asia, Europe and Eurasia, Middle East, Central and South America and Africa for a period 1990–2030 [5].