Journal of King Saud University – Engineering Sciences (2017) 29, 212–220

King Saud University

Journal of King Saud University – Engineering Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Waste-to-energy potential in the Western Province of Saudi Arabia

Omar K.M. Ouda [a], Syed A. Raza [b,*], Rafat Al-Waked [c], Jawad F. Al-Asad [d], Abdul-Sattar Nizami [e]

[a] *Department of Civil Engineering, Prince Mohammad Bin Fahd University, Khobar, Saudi Arabia*
[b] *Department of Electrical and Computer Engineering, University of Western Ontario, London, Ontario, Canada*
[c] *Department of Mechanical Engineering, Australian College of Kuwait, Kuwait*
[d] *Department of Electrical Engineering, Prince Mohammad Bin Fahd University, Khobar, Saudi Arabia*
[e] *Center of Excellence in Environmental Studies, King Abdul Aziz University, Jeddah, Saudi Arabia*

Received 12 December 2014; accepted 26 February 2015
Available online 11 March 2015

KEYWORDS

Waste-to-Energy;
Municipal solid waste;
Incineration;
Refused Derived Fuel;
Biomethanation;
Western Province of Saudi Arabia

Abstract Waste-to-energy (WTE) is a viable option for municipal solid waste (MSW) management and a renewable energy source. MSW is a chronic problem in Saudi Arabia and more specifically in Saudi Urban areas. The MSW practices in KSA are simply done by collecting the waste and dumping it in open landfill sites. KSA is considering WTE as a potential renewable energy source that can contribute to electricity demand in the Kingdom. This research aims to assess potential contribution of WTE facility to meet electricity demand in the three main cities in the Western Province of Saudi Arabia and to provide an alternative solution to landfills. Three scenarios for WTE utilization were developed: Mass Burn, Mass Burn with recycling, and refused derived fuel (RDF) with biomethanation. The Mass Burn scenario implies full waste stream incineration; the Mass Burn with recycling scenario considers segregation of reusable materials and the waste leftover for incineration; while RDF with biomethanation considers segregation of general waste stream into inorganic and organic waste and utilizes organic waste for biomethanation and inorganic for RDF. The analyses were completed for Jeddah, Makkah, and Madina cities; with current total population of about 6.3 million. The results show that Jeddah has the potential to produce about 180 MW of electricity based on incineration scenario; about 11.25 MW based on incineration with recycling scenario; and about 87.3 MW based RDF with biomethanation scenario by the year 2032. These

* Corresponding author. Tel.: +1 289 698 4095.
E-mail addresses: oouda@pmu.edu.sa (O.K.M. Ouda), srazanaq@uwo.ca (S.A. Raza), rafat@unswalumni.com (R. Al-Waked), jalasad@pmu.edu.sa (J.F. Al-Asad), nizami_pk@yahoo.com (A.-S. Nizami).
Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksues.2015.02.002

values and other two cities values are based on theoretical ideals and they help in identifying the optimal WTE techniques for each city.

Nomenclature

MSW	municipal solid waste
WTE	waste to energy
RDF	refused derived fuel
OFMSW	Organic Fraction of Municipal Solid Waste
Q_{CH_4}	annual methane generation in the year of calculation (Giga gram/y)
i	1 year time increment
j	0.1 year time increment
n	(year of calculation) − (initial year of waste acceptance)
k	methane generation constant
L_0	potential methane generation capacity (m^3/Megagram)
M_i	mass of waste accepted in the ith year
t_{ij}	age of the jth section of waste mass M_i accepted in the ith year
ERP	energy recovery potential (GWh/day)
PGP	power generation potential (MW)
NGP	net generation potential (MW)
LHV	low heating value
η	efficiency
LFG	landfill gas
PRP	power recovery potential
NCV	net calorific value
NPGP	net power generation potential

1. Introduction

Municipal solid waste (MSW) management system aims to handle health, environment, aesthetic, land-use resources, and economic concerns related to improper disposal of waste (Nemerow, 2009; Al-Waked et al., 2014; Ouda and Cekirge, 2014). Population, urbanization growth and the rise of standards of living have all dramatically accelerated the MSW generation in developing countries (Minghau et al., 2009; Guerrero et al., 2013). Developing countries are not able to cope with the MSW generation growth and open landfills remain the dominant method of disposal (Ouda et al., 2013; Ouda, 2013). The Kingdom of Saudi Arabia (KSA) is the world's largest crude oil producer and possesses the largest oil reserves (Ouda et al., 2013; Ouda et al., 2013). Crude oil revenue has come with substantial increases in population, urbanization, and the standards of living in the country (Ouda et al., 2013). The population growth of an average 3.4% over the last four decades coupled with an increase in the urbanization level from about 50% of the total population in 1970 to about 80% at present; has resulted in substantial growth of MSW generation in the country (Ouda et al., 2013; CDSI, 2010). The current municipal solid waste management system in the KSA is simple: collect and dispose off by dumping it in open landfill sites (Ouda et al., 2013). Most of the landfills are mature and are expected to reach their capacities within a few years (Ouda et al., 2013). The substantial quantity generated by MSW and the high energy contents of its composition demonstrate the significant potential of WTE facilities in KSA (Ouda et al., 2013). The KSA is planning to generate 54 GW from nuclear and renewable energy sources including WTE facilities within two decades (KACARE). The potential contribution of WTE facilities in meeting the electricity demand in KSA is hardly investigated.

2. Waste to energy technologies

There are primarily five widely used and implemented technologies for MSW management namely: incineration with energy recovery, pyrolysis or gasification, plasma arc gasification, refused derived fuel (RDF) and biomethanation i.e. anaerobic digestion. In this study, three technologies were considered for analysis: incineration, RDF and biomethanation. These technologies were chosen on the basis of lower capital cost (ton/year), net operational cost per ton, complexity of technology and higher efficiency as compared to plasma arc gasification and pyrolysis (Greater London Authority, 2008; Sorenson, 2010; Clark et al., 2010; CHAMCO; KMC).

Incineration is the production of energy from waste through combustion. There are a number of well-developed techniques across the globe (Frigon and Guiot, 2010; Tchobanoglous et al., 1993; Denac et al., 1990; Kameswari et al., 2007). Incineration remained to be the most integral part of MSW management in many countries. In the incineration process, waste feedstock is mixed thoroughly to maintain a more constant heating value and then loaded into a large hopper, bunker, or other delivery system. Feedstock is then delivered along a conveyor or other mechanism into the furnace, typically onto a graded stoker or other bed for combustion. This consists of directly burning the waste in excess oxygen with temperatures in excess of 800 °C. As the waste is incinerated, released heat travels upward and heats water in a boiler system, which in turn drives a steam cycle and steam turbine. The most important byproduct of incineration is the bottom ash which consists of silicon, iron, calcium, aluminum, sodium and potassium in their oxide state (Electricity for Europe, 2003; Psomopoulos et al., 2009). These materials are present within a range of 80–87% by mass in the bottom ash. This process also has the advantage of reducing