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ORIGINAL ARTICLE

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

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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

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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

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waste by 80% and mass by 70% and relatively lower cost in comparison to other technologies (Cheng and Hu, 2010; Rogoff and Screve, 2011). Additionally, this process can handle all types of waste including organic materials and requires low level of technology and human resource skills. The major drawback of incinerator is the generation of high levels of air and waterborne pollutants. After considering the losses in the technology, the overall efficiency of this technology is about 25% (Ouda et al., 2013). Performing incineration with recycling involves an initial stage at which the waste is segregated into recyclable and non-recyclable contents. Those materials which cannot be recycled are passed through for mass burn.

RDF is a clean and efficient method of producing an eco-friendly and an alternative fuel for power generating industries, which run on coal fuel (Nabeshima, 1996). The RDF particles are mixed thoroughly with binders such as calcium hydroxide. CaO is added to the refuse during the RDF production (Churney et al., 1989; Tatemoto et al., 1998). CaO reacts with water to become $Ca(OH)_2$. When flue gas is used as the drying gas, $Ca(OH)_2$ reacts with CO_2 to become $CaCO_3$ (Weinell et al., 1992). Then it is converted into pellets for required sizes and shapes. The RDF is formed into a chalk-like shape or pellet with a diameter of 15 mm and a length of 50mm. A RDF pellet having about 11% or more particulate calcium hydroxide is utilized in a combustible mixture. Combustion of the mixture is effective to produce an effluent gas from the combustion zone having a reduced SO_2 and polycyclic aromatic hydrocarbon content of effluent gas from similar combustion materials not containing the calcium hydroxide. The overall efficiency for this methodology is reported to be around 18% (Metro Waste Authority, 2013). RDF is mostly utilized for pulp, paper industry and the wood industry waste, followed by the saw-mill industry. Accordingly the RDF facilities are relatively small and utilized specifically by industrial sector.

Biomethanation converts the Organic Fraction of Municipal Solid Waste (OFMSW) into useful energy (Chakraborty et al., 2013). The basic raw materials for biomethanation may vary and studies show that this may contain vegetable market waste, agricultural waste, whey, dairy waste and restaurant waste (Malakahmad et al., 2012; Kameswari et al., 2007; Samuel et al., 2006; Chartrain et al., 1987; Gotmare et al., 2011). The effective efficiency of this technology is around 25% (Metro Waste Authority, 2013). The glaring disadvantage of using this process is the space requirement. The waste collected for this technique has to be properly covered for the anaerobic processes to take place and cannot be opened for the next few years, making that space unavailable for the next few years (Gotmare et al., 2011). This fact has limited its application in urban areas.

3. Objective and methodology

This paper evaluates the potential electricity generation from WTE in the three main cities in the Western Province of Saudi Arabia. The analysis will consider three scenarios for WTE development: Mass Burn, Mass Burn with recycling and RDF with biomethanation. The Mass Burn scenario implies full utilization of MSW for WTE production. Mass Burn with recycling assumes removal of all potentially recyclable materials from the waste stream and utilizing the remaining MSW for WTE production. RDF with biomethanation considers segregation of general waste stream into inorganic and organic waste. The inorganic waste is then considered for RDF methodology while organic for biomethanation.

The year 2012 was chosen as the starting year for forecasting. The MSW production rate was assumed to be 1.4 kg/capita/day (Minghau et al., 2009). There are three major cities in the western province of KSA, Jeddah with 3.4 million, Makkah with 1.7 million, and Madinah with 1.2 million (CDSI, 2010) as shown in Fig. 1. The population growth is projected to maintain its historical trend of 3.4%, which is the average growth of population in KSA, for year up to the year 2032, the total MSW generation is forecasted accordingly for the three cities.

The calorific energy content of the various types of waste is listed in Table 1 (Chartrain et al., 1987). These measures were used to calculate the total energy content per kilogram of Saudi municipal waste. There are a number of developed and emerging technologies that can produce energy from waste. The most widely used and proven WTE is the process of producing energy in the form of heat and/or electricity from waste sources via combustion (Gotmare et al., 2011; Metro Waste Authority, 2013; Gendebien et al., 2003; Gilbert et al., 2008). The research literature has documented a combustion efficiency of 25–30% for operated WTE facilities in different places across the globe (Ouda et al., 2013; KMC; Frigon and Guiot, 2010; ASME, 2008; UNEP, 1996) and around 18% for RDF (Cheng and Hu, 2010). Methane conversion to energy is reported to be around 30% (Nabeshima, 1996).

3.1. Estimation of methane

The annual methane emission from Saudis three landfill sites can be estimated using the USEPA LandGEM model. LandGEM is based on a first-order decomposition rate equation that quantifies emissions from the decomposition of landfilled municipal solid waste (MSW). The software provides a relatively simple approach to estimating landfill gas emissions. Model defaults are based on empirical data from U.S. landfills. Field test data can also be used in place of model defaults when available.

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_0 \left(\frac{M_i}{10}\right) e^{-kt_{ij}} \quad (1)$$

where Q_{CH_4} is the annual methane generation in the year of the calculation (Giga gram/y), i is the 1-year time increment, j is the 0.1-year time increment, n is the (year of the calculation) − (initial year of waste acceptance), k is the methane generation constant (y − 1), L_0 is the potential methane generation capacity m^3/Mega gram,M_i is the mass of waste accepted in the ith year (Mega gram), t_{ij} is the age of the jth section of waste mass M_i accepted in the ith year (Chakraborty et al., 2013).

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Fig. 1 Map of Saudi Arabia showing the western province with selected cities for the study. *Source:* www.brotherpete.com.

3.2. Maintaining the integrity of the specifications

In order to evaluate the energy generation potential from MSW, Table 1 is used to calculate the lower heating value of the waste by considering the dry solid waste without moisture content (Cheng and Hu, 2010). For bulk incineration process the average value of the total waste is considered as a lower heating value. For incineration with recycling all types of waste that could be recycled are excluded from the calculations. In case of RDF with biomethanation, the waste is segregated between organic and non-organic waste. In order to calculate the lower heating value (LHV) for this process, the organic waste is excluded from the general stream and the calculations are performed on the remaining waste stream including paper, plastic, glass, wood, textiles and others. The energy recovery potential (ERP) (GWh/day), Power generation potential (PGP) (MW) and Net generation potential (NGP) (MW) are given by Eqs. (2) and (3).

$$\mathrm{ERP}\left(\frac{\mathrm{GWh}}{\mathrm{day}}\right) = \left(\mathrm{DryWaste}\left(\frac{\mathrm{tones}}{\mathrm{day}}\right) \times \mathrm{LHV\ of\ waste}\left(\frac{\mathrm{kW\,h}}{\mathrm{kg}}\right)\right)/1000 \quad (2)$$

$$\mathrm{NGP} = \eta\mathrm{PGP} \quad (3)$$

where η is the efficiency of the process. Efficiency for incineration is taken as 25% and for RDF is taken as 18% (Chakraborty et al., 2013).

3.3. Heat to power generation potential calculation by biomethanation process

The biomethanation process is preferred for organic waste stream with moisture content to allow for microbial activity. The typical conversion efficiency for this process is taken as 30% (Churney et al., 1989). The values for the total land fill gas (LFG) generation are taken for LandGEM model.

$$\mathrm{PRP(MW)} = \frac{\left(\mathrm{TMG}\left(\frac{\mathrm{m}^3}{\mathrm{day}}\right) \times \mathrm{NCV} \times 365.25\right)}{1000} \quad (4)$$

$$\mathrm{NPGP(MW)} = \frac{\left(\mathrm{TMG}\left(\frac{\mathrm{m}^3}{\mathrm{day}}\right) \times \mathrm{NCV} \times \eta \times 365.25\right)}{1000} \quad (5)$$

where PRP is the power recovery potential, NCV is the Net Calorific Value of LFG and lies in the range 0.194–0.242 kW/m^3, NPGP is the net power generation potential η, is the efficiency of the bio-chemical process (Chakraborty et al., 2013).

Table 1 Energy content of different types of wastes (Rogoff and Screve, 2011).

Type of waste	Energy content (Btu/lb)
Mixed paper	6800
Mixed food waste	2400
Mixed green yard waste	2700
Mixed plastic	14,000
Rubber	11,200
Leather	8000
Textiles	8100
Demolition softwood	7300
Waste hardwood	6500
Coal	12,300
Fuel, oil	18,300
Natural gas	23,700

Table 2 Saudi Arabia's MSW energy contents.

Material	Waste composition(%)	kW h/kg in material	kW h/kg in waste HHV
Paper	28.5	4.39	1.21
Plastic	5.2	9.05	0.46
Glass	4.6	0.00	0.00
Wood	8	4.73	0.24
Textiles	6.4	5.20	0.22
Organic	37.0	1.55	0.10
Others	10.3	3.36	0.28
Total energy for mass burn with recycling scenario (kW h/kg)			0.377
Total energy contents of mass burn scenario (kW h/kg)			2.512

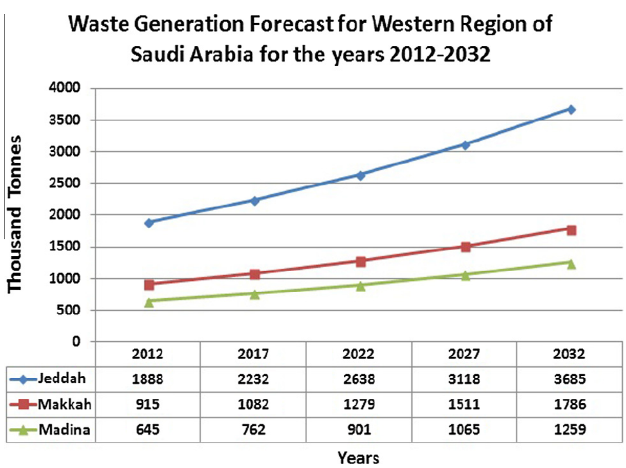

Fig. 2 Waste generation forecast for the three main cities in the Western Province of Saudi Arabia for the years 2012–2032.

4. Results and discussion

4.1. MSW composition and quantity forecast

The waste composition for Saudi Arabia is tabulated in Table 2 for the year 2012 along with the LHV value for each type of waste using the values from Table 1. The MSW wastes of the KSA include 37% organic materials, 28.5% paper, 5.2% plastics, 8.3% mineral, 4.6% glass, 8% wood, 6.4% textile, and 2% others (Ouda et al., 2013; Rogoff and Screve, 2011). The waste distribution as listed in Minghau et al. (2009), UNEP (1996) is an average of waste collected in the kingdom. By considering the same distribution, study of power generation can be forecasted for different cities. The last two columns of Table 2 represent the total energy and the LHV in the material.

The forecasted MSW quantity per year for the three cities and up to year 2032 is presented in Fig. 2. The figure shows that by the year 2032, about 6730 thousand tons of MSW will be generated in the three cities, out of which 55% will be from Jeddah city. With this huge quantity if not managed properly, severe environmental consequences can be anticipated in the long-term.

4.2. Methane gas generation

For the estimation of methane from landfill sites, user specified inputs are used in the LandGEM model. The methane generation potential (L_0) is specified as a default value of 61 m^3/Mg, while the methane generation constant (k) is specified as 0.026 per year. The methane and carbon dioxide in the LFG are considered to be 50%. For the purpose of this study it is assumed that the three landfill sites in Makkah, Madina and Jeddah have started operation in 2012 and the waste is accumulated up to the year 2032. Biomethanation for this study is applied with RDF which takes the organic waste as input. The result

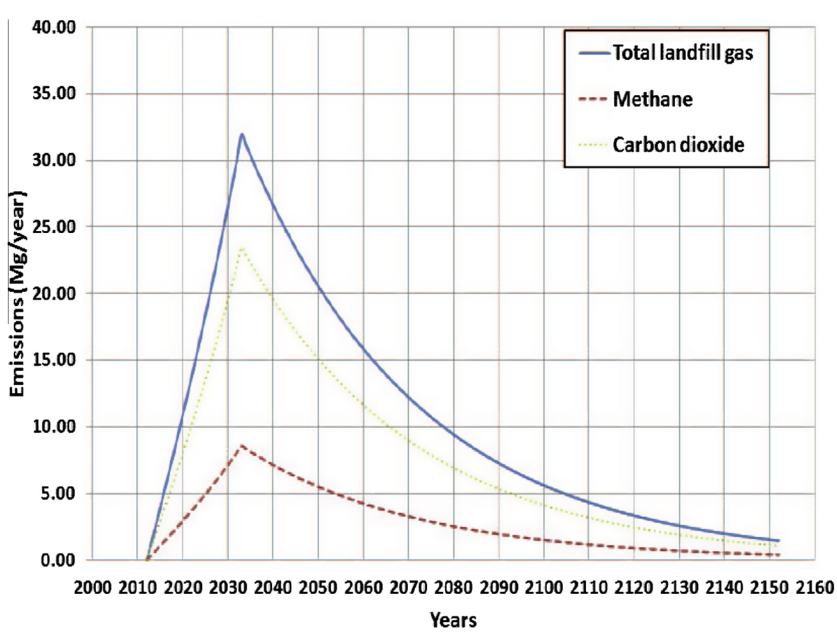

Fig. 3 Landfill gas emission estimation for RDF with biomethanation technology for Makkah site for the years 2012–2152.

for the total LFG generation in the landfill sites is shown in Figs. 3–5. The LFG forecast results for Makkah, Madina and Jeddah cities are presented in Figs. 3–5, respectively. The total LFG for Makkah, Madina and Jeddah are calculated as 31.20, 22.54 and 65.97 Mg/year, respectively. The methane generation for Makkah, Madina and Jeddah are calculated as 8.54, 6.02 and 17.62 Mg/year and for carbon dioxide as 23.43, 16.52 and 48.34 Mg/year, respectively.

The model proposes that the landfills will reach their full capacity in the year 2032. The peak of landfill gas generation will occur one year after, i.e., in the year 2033. Following the peak year, landfill gas generation will continue at a declining rate as long as the biochemical degradation of organic waste occurs. The complete degradation of organic waste may take more than a century to be completed.

4.3. WTE scenario results

Three scenarios for WTE were developed and analyzed: Mass Burn, Mass Burn with recycling and RDF with Biomethanation. The forecast results by the year 2032 for the three scenarios for Makkah, Madina and Jeddah cities

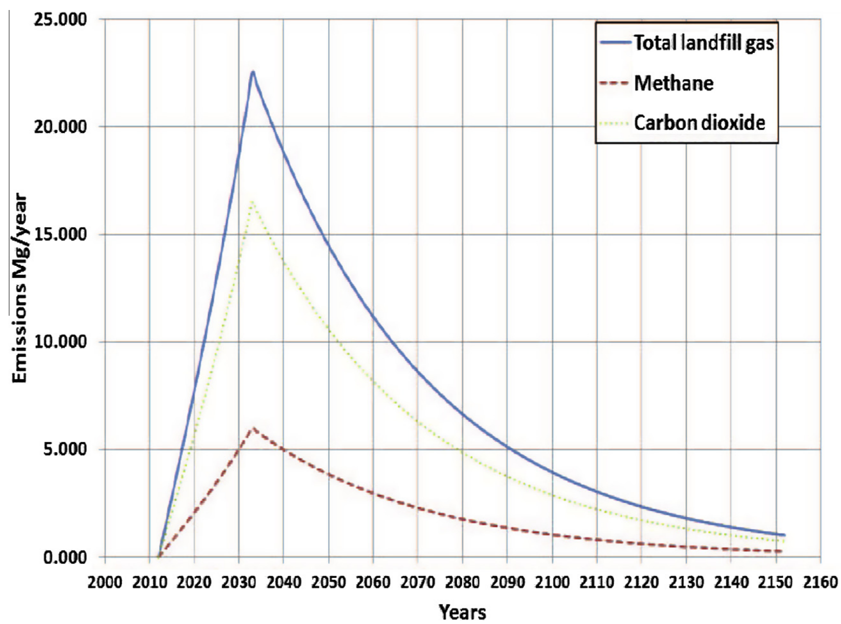

Fig. 4 Landfill gas emission estimation for RDF with biomethanation technology for Madina site for the years 2012–2152.

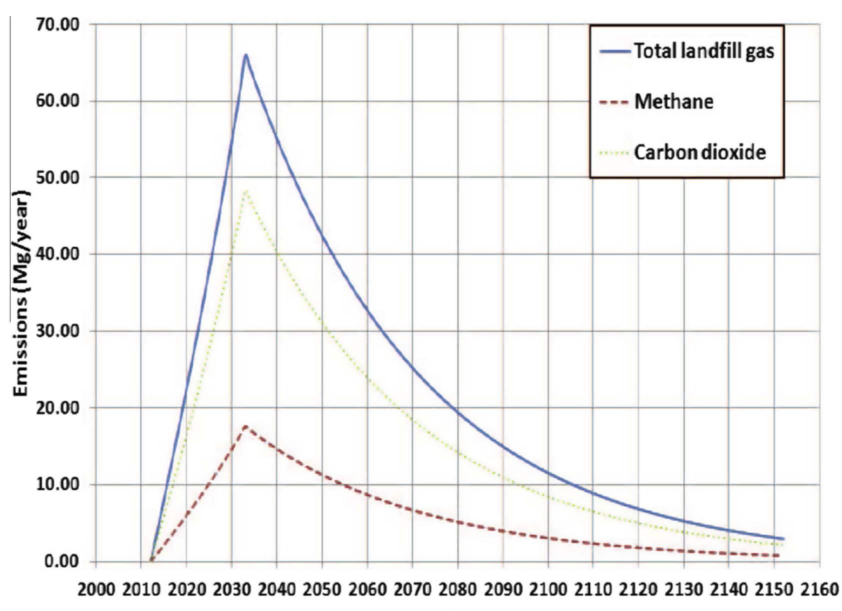

Fig. 5 Landfill gas emission estimation for RDF with biomethanation technology for Jeddah site for the years 2012–2152.

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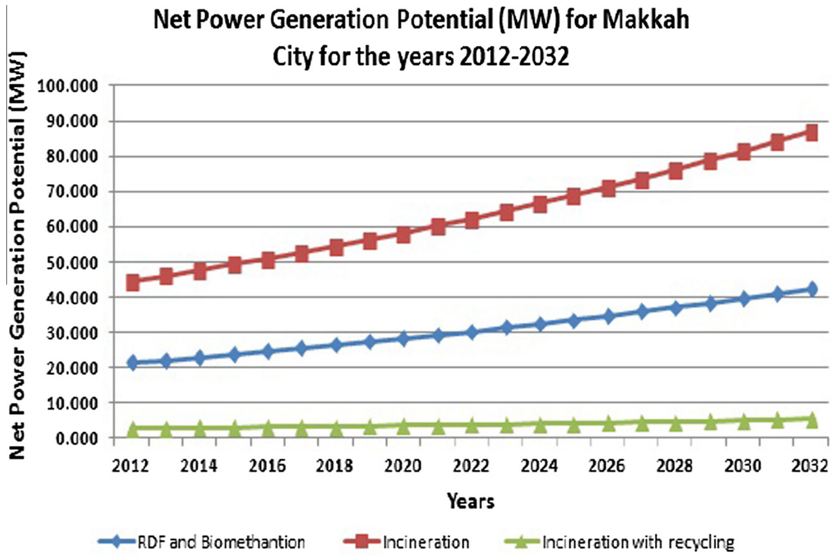

Fig. 6 Net power generation potential (MW) for Makkah city for the years 2012–2032.

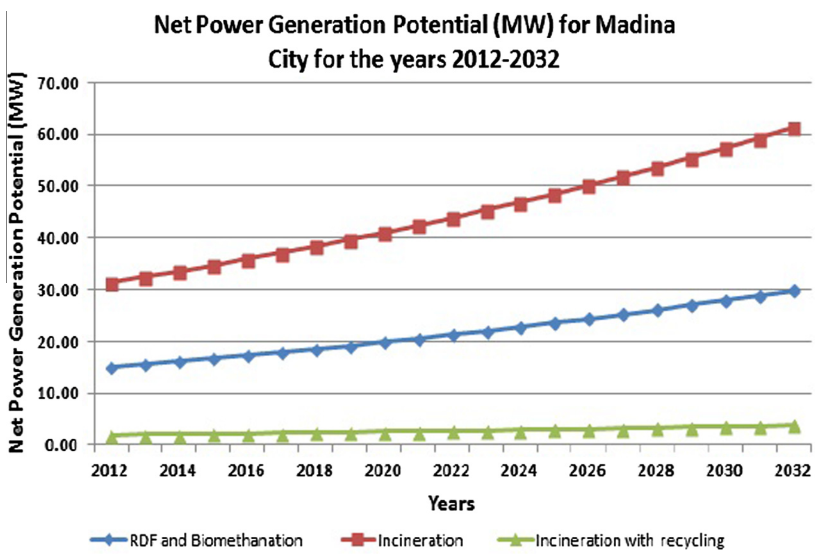

Fig. 7 Net power generation potential (MW) for Madina city for the years 2012–2032.

are presented in Figs. 6–8 respectively. The figures show that for the Mass Burn Scenario there is a potential to generate about 87.0, 61.3 and 180.0 MW from Makkah, Madina and Jeddah cities respectively. The Mass Burn with recycling scenario shows a potential to produce about 5.45, 3.84 and 11.25 MW from Makkah, Madina and Jeddah cities respectively.The RDF with Biomethanation Scenario shows a potential to produce about 42.4, 29.9 and 87.3 MW from Makkah, Madina and Jeddah cities, respectively.

The figures also show that Mass Burn Scenario has the highest power generation capacity over the other two scenarios. Additionally, the three scenarios provide a viable disposal option for MSW and, if implemented, will alleviate the landfills site problem in the area. The choice from among the three scenarios requires further financial, social, technical, and environmental analyses. However the decision to select a particular scenario is crucial and should be taken at a political level based on the results of intensive research.

5. Future work

The choice from among the three scenarios discussed in this paper requires further financial, social, technical, and environmental analyses which the authors are working on as an extension of this work. It will be worth looking at the capital cost per ton, operational cost, complexity of technologies, labor skill levels and geographical location for implementing each of these scenarios. By looking at the global trend of actual implementation of these processes, it will be possible to

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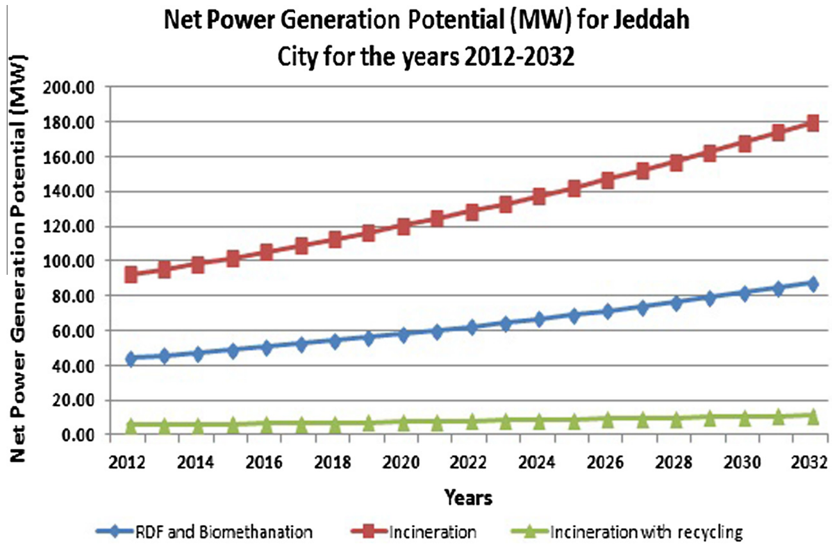

Fig. 8 Net power generation potential (MW) for Jeddah city for the years 2012–2032.

determine their feasibility in KSA. However the decision to select a particular scenario is crucial and should be taken at a political level based on the results of intensive research.

6. Conclusion

The MSW practices in KSA are simply done by collecting waste and disposing it off by dumping it in open landfill sites. This practice has created a chronic MSW disposal problem in the Kingdom. KSA is considering WTE as a potential renewable energy source that can contribute to electricity demand in the Kingdom and alleviate the MSW disposal problem. This research has assessed the potential contribution of WTE facility to meet electricity needs in the three main cities in the Western Province of Saudi Arabia and provided a solution to landfill sites problem. Three scenarios for WTE were developed and analyzed: Mass Burn, Mass Burn with recycling and RDF with Biomethanation. The scenarios were forecasted up to year 2032. The research results show that Mass Burn Scenario has the highest power generation capacity over the other two scenarios. Additionally, the three scenarios provide a viable disposal option for MSW and, if implemented, will alleviate the landfill problem in the area.

References

Al-Waked, R., Ouda, O.K.M., Raza, S.A., 2014. Potential value of waste-to-energy facility in Riyadh city-Saudi Arabia. JIMEC.
ASME, American Society of Mechanical Engineers, 2008. Waste-to-energy: A Renewable Energy Source From Municipal Solid Wastes. Tech. rep.
CDSI, Population & Housing Census for 1431 A.H (2010 A.D) Findings, 2010. Tech. rep., CDSI, Central Department of Statistics & Information. URL http://www.cdsi.gov.sa/.
Chakraborty, M., Sharma, C., Paney, J., Gupta, P.K., 2013. Assessment of energy generation potentials of MSW in Delhi under different technological option. Energy Convers. Manage. 75, 249–255.
CHAMCO. Garbage electricity. URL http://www.chamco.net/chamco/garbageelectricity.html.
Chartrain, M., Bhatnagar, L., Zeikus, J., 1987. Microbial ecophysiology of whey biomethanation: comparison of carbon transformation parameters, species composition and starter cultural performance in continuous culture. Appl. Environ. Microbiol., 1147–1156
Cheng, H., Hu, Y., 2010. Review: Municipal solid waste (MSW) as a renewable source of energy: current and future practices in China. Bioresour. Technol. 101, 3816–3824.
Churney, K.L., Ledford Jr., A.E., Buckley, T.J., Domalski, E.S., 1989. Chlorine mass balance in the combustion of refuse-derived fuel. Resour. Conserv. 14, 249–256.
Clark, B., Rogoff, M., 2010. Economic feasibility of a plasma arc gasification plant, city of Marion, Iowa. In: Proceedings of 18th Annual North American Waste-to-Energy Conference.
Denac, M., Lee, P.L., Newell, R.B., Greenfield, P.F., 1990. Automatic control of effluent quality from a high rate anaerobic treatment system. Water Res. 24, 583.
Electricity for Europe (Eurelectric)., 2003. Efficiency in Electricity Generation. URL www.eurelectric.org%2FDownload%2FDownload.aspx%3FDocumentID%3D13549&ei = 3Y3-UOmdJI6X0QXJqYGIDQ&usg = AFQjCNH41MwVJ57EVzrpWHxpDmc1WkZ-w.
Frigon, J., Guiot, S., 2010. Biomethanation production from starch and lignocellulosic crops: a comparative review. Biofuels Bioproducts Biorefin. 4 (2), 447–458.
Gendebien, A., Leavens, A., Blackmore, K., Godley, A., Lewin, K., Whiting, K.J., 2003. Refuse Derived Fuel, Current Practice and Perspectives Final Report. Tech. rep.
Gilbert, M., Wendell, P., 2008. Introduction to environmental engineering and science. In: Solid Waste Management and Resource Recovery, third ed. Pearson Education Inc. (Ch. 9.).
Gotmare, M., Dhoble, R., Pittule, A., 2011. Biomethanation of dairy waste water through UASB at mesophilic temperature range. Int. J. Adv. Eng. Sci. Technol. 8 (1), 001–009.
Greater London Authority, 2008. Cost of Incineration and Non-Incineration Energy-from-waste-technologies, January 2008, Tech. rep. URL http://legacy.london.gov.uk/mayor/environment/waste/docs/efwtechnologiesreport.pdf.
Guerrero, L., Mass, G., Hogland, W., 2013. Solid waste management challenges for cities in development countries. J. Waste Manage. 33, 220–232.
KACARE, Renewable Energy – Waste to Energy, A Pillar of the Sustainable Energy Kingdom. Tech. rep., First International Environment Conference, King Fahd Civic Centre, Yanbu Al Sinaiyah, KSA.

Kameswari, K., Velmurugan, B., Thirumaran, K., Ramanujam, R., 2007. Biomethanation of Vegetable Market Waste Untapped Carbon Trading Opportunities, Tech. rep.

Kameswari, K.S.B., Velmurugan, B., Thirumaran, K., Ramanujam, R., 2007. Biomethanation of vegetable market waste untapped carbon trading opportunities. In: Proceedings of the International Conference on Sustainable Solid Waste Management, pp. 415–420.

KMC. KMC to setup biomethanation plant. URL http://www.myrepublica.com/portal/index.php?action=newsdetails&newsid=65208.

Malakahmad, A., Md Zain, S., Basri, N.E.A., 2012. Biomethanation of kitchen waste and sewage sludge in anaerobic baffled reactor. In: IEEE Symposium on Humanities, Science and Engineering Research.

Metro Waste Authority, 2012–2013. Strategic Business Plan, Metro Waste Authority, Tech. rep.

Metro Waste Authority, 2013. Alternative Disposal Feasibility, Tech. rep.

Minghau, Z., Xiumin, F., Rovetta, A., Qichang, H., Vicentini, F., Bingkai, L., Giusti, A., Yi, L., 2009. Municipal solid waste management in Pudong New Area, China. J. Waste Manage. 29, 1227–1233.

Nabeshima, Y., 1996. Technical evaluation of refuse derived fuel (RDF). Waste Manage. 7, 294–304.

Nemerow, N., 2009. Environmental Health and Safety for Municipal Infrastructure, Land Use and Planning, and Industry, sixth ed. Wiley, Hoboken, N.J..

Ouda, O., 2013. Assessment of the environmental values of waste-to-energy in the Gaza Strip. Curr. World Environ. 8 (3), 335–364.

Ouda, O.K.M., Cekirge, H.M., 2014. Potential environmental values of waste-to-energy facilities in Saudi Arabia. Arab. J. Sci. Eng. (AJSE) 39 (2), 7525–7533.

Ouda, O.K., Cekirge, H.M., Raza, S., 2013. An assessment of the potential contribution from waste-to-energy facilities to electricity demand in Saudi Arabia. Energy Convers. Manage. 75, 402–406. http://dx.doi.org/10.1016/j.enconman.2013.06.056, URL: http://linkinghub.elsevier.com/retrieve/pii/S0196890413003683.

Ouda, O., Shawesh, A., Al-Olabi, T., Younes, F., Al-Waked, R., 2013. Review of domestic water conservation practices in Saudi Arabia. Appl. Water Sci. 3, 689–699.

Psomopoulos, C., Bourka, A., Themelis, N., 2009. Waste-to-energy: a review of the status and benefits in USA. Waste Manage. 29, 1718–1724.

Rogoff, M.J., Screve, F., 2011, secpnd ed. Waste to Energy.

Samuel, C., Custudio, O., Tongco, E., Tiangco, C.C., 2006. Promotion of Renewable Energy, Energy Efficiency and Green House Gas Abatement (PREGA) Philippines Waste to energy Project. Tech. rep., Pineapple Processing Waste Biomethanation and Treatment Plant A Prefeasibility study report, prepared by PREGA National Technical Experts from CPI Energy Philippines.

Sorenson, C. A., 2010. Comparative Financial Analysis of Fast Pyrolysis Plants in South West Oregon (Ph.D. thesis).

Tatemoto, Y., Bando, Y., Yasuda, K., Nakamura, M., Azegami, M., 1998. Rotting prevention by added CaO in RDF production. J. Chem. Eng. 5, 846–847.

Tchobanoglous, G., Theisen, H., Vigil, S., 1993. Integrated Solid Waste Management. Engineering Principles and Management Issues, McGraw Hill Singapore.

UNEP, United Nations Environmental Program, 1996. International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management. Tech. rep.

Weinell, C.E., Jensen, P.I., Dam-Johansen, K., Livbjerg, H., 1992. Hydrogen chloride reaction with lime and limestone: kinetics and sorption capacity. Industr. Eng. Chem. Res. 31, 164–171.