ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 2616-4302
CODEN: AMMCFL

Acta Mechanica Malaysia (AMM)

DOI : http://doi.org/10.26480/amm.01.2019.11.15

CrossMark

RESEARCH ARTICLE

POTENTIAL OF MUNICIPAL SOLID WASTE IN LIBYA FOR ENERGY UTILIZATION

Monaem Elmnifi[1]*, Moneer Alshilmany[2], Moftah Abdraba[3]

[1]Department of Mechanical Engineering, Benghazi University, Libya
[2]Department of Electricity Engineering, Benghazi University, Libya
[3]Electricity Company, Elmarj, Libya
**Corresponding Author Email: monm.hamad@yahoo.co.uk*

ARTICLE DETAILS

Article History:

Received 27 February 2019
Accepted 25 March 2019
Available Online 23 April 2019

ABSTRACT

Municipal Solid Waste (MSW) management is a chronic environmental problem in most of the developing countries, including the Libya. The concept of Waste-to Energy (WTE) is known as one of the several technologies capable of benefiting a society, which desires to reduce fossil-fuel addiction. Currently, there is no WTE facility existing in the Libya. The MSW is collected and disposed in landfills untreated. A substantial increase in the population by 2.2 % per year over the last years coupled with urbanization and raised living standards have resulted in high generation rate of MSW. The food and plastic waste are the two main waste streams, which covers 70 % of the total MSW. The waste is highly organic (up to 72 %) in nature and food waste covers 50.6 % of it. The aim of this paper is to review the prospective WTE technologies in Libya. Three WTE scenarios were developed: complete incineration; incineration with recycling and Refused Derived Fuel (RDF) with Biomethanation. The results show that Libya has the potential to produce about 197 MW of electricity based on incineration scenario; about 57 MW based on incineration with recycling scenario; and about 76 MW based RDF with biomethanation scenario in the year 2030.

KEYWORDS

Waste-to-Energy, Municipal Solid Waste, Renewable Energy, Incineration, Libya.

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 [1-3]. Population, urbanization growth and the rise of standards of living have all dramatically accelerated the MSW generation in developing countries [4,5]. Developing countries are not able to cope with the MSW generation growth and open landfills remain the dominant method of disposal [6]. The population growth in Libya of an average 2.2% 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 [7,8]. The current municipal solid waste management system in the Libya is simple: collect and dispose off by dumping it in open landfill sites [6]. Most of the landfills are mature and are expected to reach their capacities within a few years. The substantial quantity generated by MSW and the high energy contents of its composition demonstrate the significant potential of WTE facilities in Libya.

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 [9,10]. Incineration is the production of energy from waste through combustion. There are a number of well-developed techniques across the globe [11-13].

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 by product of incineration is the bottom ash which consists of silicon, iron, calcium, aluminum, sodium and potassium in their oxide state [14,15]. These materials are present within a range of 80–87% by mass in the bottom ash. This process also has the advantage of reducing waste by 80% and mass by 70% and relatively lower cost in comparison to other technologies [16,17]. 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% [18]. 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 [19]. The RDF particles are mixed thoroughly with binders such as calcium hydroxide. CaO is added to the refuse during the RDF production [20]. CaO reacts with water to become Ca(OH)2. When flue gas is used as the drying gas, Ca(OH)2 reacts with CO2 to become CaCO3 [21]. Then it is converted into pellets for required sizes and shapes. The RDF is formed into a chalklike 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 SO2 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% [22]. 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 [23]. 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 [24,25]. The effective efficiency of this technology is around 25% [22]. 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 [26]. This fact has limited its application in urban areas. The diagram shown in Figure 1 shows the procedure for municipal solid waste generation and municipal waste management series. The diagram also shows the procedure from local solid waste analysis to energy analysis [26].

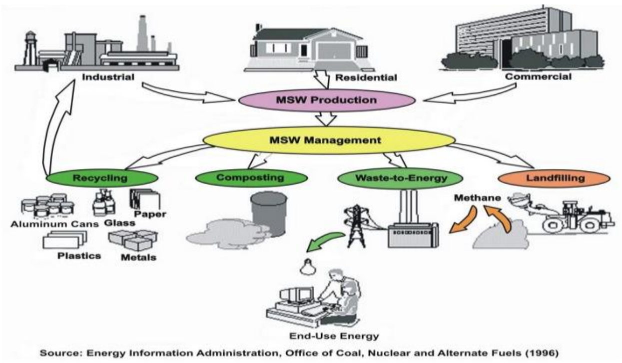


Figure 1: MSW generation and management

3. OBJECTIVE AND METHODOLOGY

This paper evaluates the potential electricity generation from WTE in Libya. 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 1.3 kg/capita/day [27]. The population of Libya with 5.8 million [28]. The population growth is projected to maintain its historical trend of 2.2%, which is the average growth of population in Libya, for year up to the year 2030.

The thermal energy content of different types of waste is listed in Table 1[29]. These measures were used to calculate the total energy content per kilogram of Libya municipal waste. There are a number of developed and emerging technologies that can produce energy from waste. The most used and proven WTE is the process of producing energy in the form of heat and/or electricity from waste sources via combustion. The research literature has documented a combustion efficiency of 25–30% for operated WTE facilities in different places across the globe and about18% for RDF. Methane conversion to energy is reported to be about 30% [30, 31].

Table 1: Energy content of different types of wastes.

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**

3.1 Estimation of methane

The most important factor to determine the amount of biogas is the content of carbon in the organic matter where it breaks down, some carbon is in the composition of microbes and the rest of the carbon shall be methane and carbon dioxide and to. Calculate the proportion of methane gas follows: The amount of carbon expressed by the percentage of organic waste as shown in Table 2.

Table 2: Amount of carbon expressed by the percentage of organic waste

Materials	The amount of carbon %
paper	**40**
Textiles	**40**
Wood	**30**
Agricultural waste	**17**
Food waste	**15**

Where food and paper are separated from the rest of the waste. Residues of food and agricultural waste remain the proportion of organic waste in Libya is 80% and the remaining 20% agricultural waste. Carbon ratio is (80% * 15% + 20% * 17%) = 0.154 kg carbon / kg waste. The amount of carbon responsible for the generation of methane is calculated by equation 1[8].

$$\frac{\text{Coe}}{\text{Co}} = 0.014\,T + 0.28 \qquad 1$$

Temperature

T- Celsius

C_{oe} - The amount of carbon available to generate methane

C_o - Total amount of carbon in waste

$$\frac{\text{Coe}}{\text{Co}} = 0.014(36) + 0.28 = 0.784$$

Co = 0.16

Coe = 0.1207 kg

$$Quantity\ of\ methane = 0.1207 * \left(\frac{12}{16}\right) = 0.1609\ (\ Kg.CH4/Kg.waste)$$

3.2 Calculations for heat to power generation potential

In order to assess the potential of generating power from Domestic solid waste, Table 1 is used to calculate the heating value less than Waste by looking at dry solid waste without moisture Content. For the wholesale burning process the average value of total waste is lower heating value. For incineration with recycling all types of waste that could be recycled are excluded from the calculations. In the case of RDF with biomethanithion, the waste is Isolated between organic and inorganic waste. Salary To calculate the heating value less (LHV) for the process, Organic waste is excluded from the general flow Calculations are made of residual residues 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 Esq. (2) and (4) [18].

$$ERP\left(\frac{GWh}{day}\right) = \frac{\left[Dry\ waste\left(\frac{tons}{day}\right) * LHV\ of\ waste\left(\frac{KWh}{kg}\right)\right]}{1000} \qquad 2$$

$$PGP(MW) = \frac{\left[Dry\ waste\left(\frac{kg}{s}\right) * LHV\ of\ waste\left(\frac{kw}{kg}\right)\right]}{1000} \qquad 3$$

$$NGP = \eta * PGP \qquad 4$$

Where η is the efficiency of the process. Efficiency for incineration is taken as 25% and for RDF is taken as 18.

3.3 Heat to power generation potential calculation by biomethanation process

The bio-methane process of organic waste stream is preferred with moisture content to allow for microbial activity. The typical conversion efficiency of this process is 30%.

$$ERP(MW) = \frac{\left[T\,MG\left(\frac{m^3}{day}\right) * NCV * 365\right]}{0.042 * 1000 * 24} \quad 5$$

$$NGP(MW) = \frac{\left[TMG\left(\frac{m^3}{day}\right) * NCV * 365\right]}{1000} \quad 6$$

Where NCV is the Net Calorific Value and lies in the range 0.194-0.242 kW/m3 and η is the efficiency for the bio-chemical process.TMG Total Methane Generation [18].

4. RESULTS AND DISCUSSION

4.1 MSW composition and quantity forecast

Table 3 shows the composition of waste in Libya together with high value values for each type of waste using the values in Table 1. Municipal solid waste wastes consist of 56.3% organic matter, 13.5% paper and 10.3% plastic 3.7% of metals, 2.6% glass, 2. 8% of wood, 10.8% of fabric. The diagram shown in Figure 2 shows the composition of waste in Libya [32].

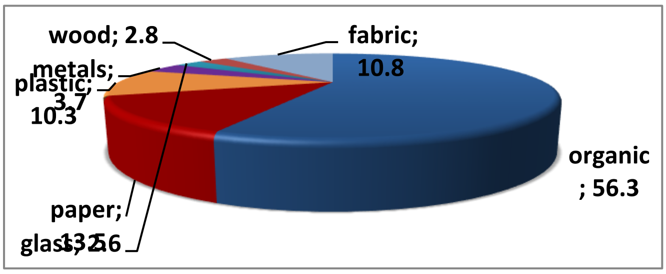


Figure 2: Shows the composition of waste in Libya

Table 3: Libya MSW energy content

Material	Waste composition %	Energy content (Btu/Ib)	KW h/Kg Material	KW h/Kg in Waste HHV
Paper	13.5	6800	4.39	0.58
Plastic	10	14000	9.05	0,905
Glass	2.6	0	0	0
Wood	2.8	7300	4.73	0.132
Textiles	10.8	8100	5.20	0.561
Organic	56.3	2400	1.55	0.872
Others	5.7	5200	3.36	0.191
Total energy for mass Burn with recycling scenario (KW h/kg)				1.443
Total energy contents of mass Burn scenario (KW h/kg)				3.289

4.2 Libya MSW input data

MSW data are collected from Libya during the period of (2012 – 2030). In 2006, the percentage of MSW per capita was about 0.915 kg / day, while in 2010 the proportion of the individual production of MSW was 1.1 kg per day. The Municipal Solid Waste (MSW) generation in the Middle East and North Africa is estimated about 0.16 to 5.7 kg /person/day, with an average of 1.1 kg/capita/day. Based on the previous researches and our calculations the rate of 1.3 is used in this study. The technical data for MSWI potential for Libya is shown in table 4 [27].

Table 4: Technical data for MSWI potential of Libya

Year	Citizens [pears]	Waste indicators [kg/pres/ day]	Waste quantity [kg/pres/ day]	Waste quantity [ton/year]	The cumulative amount of waste
2012	**5878100**	**1.3**	**7641530**	**2789158**	**2789158**
2015	**6759815**	**1.3**	**8787759**	**3207532**	**5996690**
2020	**7773787**	**1.3**	**10105923**	**3688325**	**9685015**
2025	**8939855**	**1.3**	**11621812**	**4241665**	**13926680**
2030	**10280833**	**1.3**	**13365083**	**4878225**	**18804905**

The forecasted MSW quantity per year for Libya up to year 2030 is presented in Figure 3. The figure shows that by the year 2030, about 4,8 thousand tons of MSW. This is a huge quantity and should be managed properly otherwise a severe environmental consequence can be anticipated in the long-term.

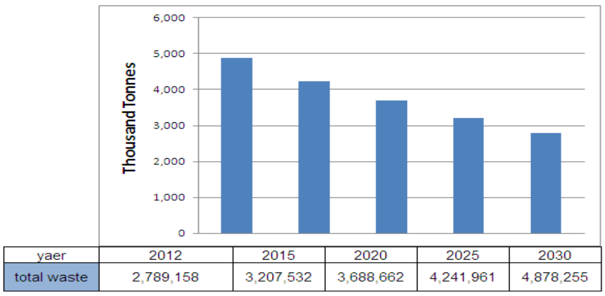
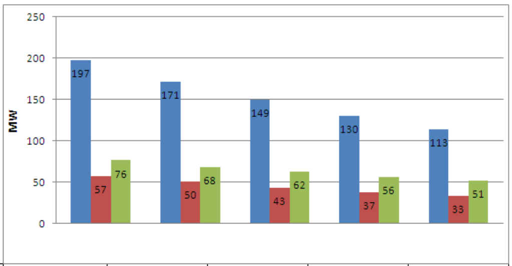


Figure 3: Waste Generation Forecast for Libya up to year 2030

4.3 WTE Scenario results

Three scenarios for WTE development were developed and analyzed: complete incineration; incineration with recycling; and RDF with biomethanation. The forecast results for three scenarios for Libya is presented in figure 4. The figure shows that for the incineration scenario has a potential to generate about 197 MW in 2030 while incineration with recycling scenario shows a potential to produce about 57 MW in 2030. The RDF with biomethanation scenario shows a potential to produce about to produce about 76 MW in 2030 from Libya.

The figure also shows that complete incineration scenario has the highest power generation capacity over the other three scenarios. Additionally, the three scenarios provide a viable disposal option for MSW and, if implemented, will alleviate the landfills problem in the area. The decision to select among the three scenario will required further financial, social, technical, and environmental analysis.



yaer	2012	2015	2020	2025	2030
complete incineration	113	130	149	171	197
incineration with recycling	33	37	43	50	57
Refused Derived Fuel (RDF) with Biomethanation	51	56	62	68	76

Figure 4: Power Generation Potential (MW) of Libya for the years 2012-2030

5. FUTURE WORK

Choose from the three scenarios discussed in this the paper requires more financial, social, technical and environmental analyses in which the authors work of this work. It will be useful to consider the cost of capital Ton, operational cost, complexity of technologies, and work Skills levels, and geographic location for their respective implementation of these scenarios. By looking at the actual global trend the implementation of these operations, will be possible.

6. CONCLUSION

Local solid waste practices in Libya are carried out simply by collecting and disposing of waste by dumping it at landfill sites. This practice has led to a chronic problem in the disposal of municipal solid waste. Libya considers vocational and commercial training to be renewable the source of energy that can contribute to the demand for electricity in the Libya and alleviate the problem of disposal of municipal solid waste. This paper assessed the potential contribution of a facility to meet the electricity needs of Libya and provided a solution to the problem of landfill sites. Three scenarios were developed and analyze: Mass Burn, Mass Burn with recycling and RDF with biomethanation. The scenarios were forecasted up to year 2030. 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

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

[2] Al-Waked, R., Ouda, O.K.M., Raza, S.A. 2014. Potential value of waste-to-energy facility in Riyadh city-Saudi Arabia. JIMEC.

[3] 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

[4] 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. Waste Management Journal, 29, 1227–1233.

[5] Guerrero, L., Mass, G., Hogland, W. 2013. Solid waste management challenges for cities in development countries. Waste Management Journal, 33, 220–232.

[6] Jalal, E. 2013. Municipal solid waste management and institutions in Tripoli, Libya: applying the Environmentally Sound Technologies (ESTs) concept [master thesis] University of Hull.

[7] Ouda, O. 2013. Assessment of the environmental values of waste-to energy in the Gaza Strip. Current World Environment, 8 (3), 335–364.

[8] CDSI. 2010. Population & Housing Census for 1431 A.H (2010 A.D) Findings. Tech. rep., CDSI, Central Department of Statistics & Information. URL http://www.cdsi.gov.sa/.

[9] 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.

[10] 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

[11] Frigon, J., Guiot, S. 2010. Biomethanation production from starch and lignocellulosic crops: a comparative review. Biofuels Bioproducts Biorefin, 4 (2), 447–458.

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

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

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

[15] Electricity for Europe (Eurelectric). 2003. Efficiency in Electricity Generation. URL www.eurelectric.org%2FDownload%2FDownload.

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

[17] Cheng, H., Hu, Y. 2010. Review: Municipal solid waste (MSW) as a renewable source of energy: current and future practices in China. Bioresource Technology, 101, 3816–3824.

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

[19] Nabeshima, Y. 1996. Technical evaluation of refuse derived fuel (RDF). Waste Management, 7, 294–304.

[20] Churney, K.L., Ledford, A.E., Buckley, T.J., Domalski, E.S. 1989. Chlorine mass balance in the combustion of refuse-derived fuel. Resources, Conservation and Recycling, 14, 249–256.

[21] Weinell, C.E., Jensen, P.I., Dam-Johansen, K., Livbjerg, H. 1992. Hydrogen chloride reaction with lime and limestone: kinetics and sorption capacity. Industrial & Engineering Chemistry Research, 31, 164–171.

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

[23] Chakraborty, M., Sharma, C., Paney, J., Gupta, P.K. 2013. Assessment of energy generation potentials of MSW in Delhi under different technological option. Energy Conversion and Management, 75, 249–255.

[24] 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.

[25] 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.

[26] Gotmare, M., Dhoble, R., Pittule, A. 2011. Biomethanation of dairy waste water through UASB at mesophilic temperature range. International Journal of Engineering and Advanced Technology, 8 (1), 001–009.

[27] http://www.worldbank.org

[28] Statistical book. 2012.bureau of statistics and census annual bulletin, state of Libya.

[29] Gilbert, M.M., Wendell, P.E. 2008. Introduction to environmental engineering and science, Chapter 9. Solid waste management and resource recovery. Pearson Education Inc. ISBN-13:978-0-13-2339346.

[30] ASME. 2008. American Society of Mechanical Engineers. Waste-toenergy: A Renewable Energy Source from Municipal Solid Wastes. Tech. rep.

[31] European Commission. 2006. Integrated Prevention and Control. Reference document on the Best Available Techniques for Waste Incineration.

[32] Elmnifi, M., Amhamed, M., Abdelwanis, N., Imrayed, O. 2017. Waste-to-energy potential in tripoli city-libya. Environment & Ecosystem Science, 2 (1), 01-03.