Technical, Economic and Environmental Analysis of Using Incinerator to Produce Energy from Municipal Solid Waste in Shiraz, Iran

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Abstract

As Shiraz population has grown significantly, an increase in the amount of waste generated is occurred in the last few years. Solid waste incineration could be potentially an option for MSW management in this city. Due to separation of solid waste at the source strategy in Shiraz, the rejected part of sorting system with LHV equal to 11120 kJ/kg is a viable option. By performing an economic assessment, it is obvious that the benefit of the project is about 280 million dollars after 30 years which shows that the project is economically sound and saves land simultaneously.

1. Introduction

Human activities generate waste materials that are often discarded because they are considered unwanted [1]. However, many of these waste materials can be reused, and a resource for industrial production or energy generation, if managed properly [1]. Because of the great migration from the countryside to the city of Shiraz, the city population has grown significantly in the recent decade which results in an increase in the amount of waste generated. A few approaches including landfilling, composting, recycling, mechanical-biological treatment, and waste to energy (WTE) have superior influence on MSW than other existing methods [2]. Currently, the waste management approaches being employed in Shiraz are waste separation, industrial sorting, recycling, waste to energy, and composting besides the large portion of wastes being landfilled. However, due to the rapid population growth and lack of space for new landfills, methods like waste to energy should be considered more seriously. Due to the sustainability, renewability, and cleanness of this source of energy, it is considered as an alternative to landfilling [3]. The volume of incoming municipal solid waste (MSW) can be reduced by 90%-95% thanks to the use of latest WTE facilities generating energy and extending lifetime of landfills [3]. Recent technologies producing energy from MSW include incineration, gasification, generation of biogas and utilization in a combined heat and power (CHP) plant as well as generation of biogas and conversion to transport fuel [4]. Electricity can be produced by using incinerators and thus partially offset the cost of incineration process [5]. One of the aspects of waste to energy systems, is using incinerators. Although the incineration method has been introduced in different countries, municipality of Shiraz has not employed it yet for waste management.

In this paper, we investigate the benefit of incinerators for disposal of the rejected wastes from solid waste sorting system in terms of administrative and economic aspects. A simple evaluation is conducted to establish the amount of energy that would be recovered based on the characteristics of the MSW if it is to be incinerated.

2. MSW quantification and composition in Shiraz

A survey carried out every year by MSW Management Company of Shiraz municipality showed that the generation of MSW increased from 300395 tons in 2004 to 346092 tons in 2014, an increment corresponding at a rate of 1.9% per year (Table 1). Consequently the amount of wastes which are landfilled is increased at a rate of about 7.5%. per year. In addition, it is obvious that a large amount of (about 75%) MSW generated in Shiraz is landfilled. On the other hand, Table 2 highlights the various components of MSW in Shiraz City.

Table 1. Shiraz MSW generation and disposal from 2004 to 2014 (MSW Management Company of Shiraz municipality)

year	MSW generated	Recycled	Landfilled
2004	300395	1,239	225296
2005	321,930	1,424	241447
2006	327,770	1,763	245827
2007	352,955	1,954	264716
2008	361,350	2,711	271012
2009	350,278	5,061	262708
2010	352,678	8,871	264508
2011	349,141	12,677	261855
2012	337,246	11,664	252934
2013	335,053	16,204	251290
2014	346,092	21,755	259570

Table 2. Components of MSW in Shiraz City (MSW Management Company of Shiraz municipality)

Material	percent
Organics	66.27
paper	5.38
plastics	10.66
metals	1.76
glass	2.40
Non recyclable materials	13.63
total	100

According to Table 2, organic materials make up the largest portion of MSW in Shiraz city.

Based on the investigations carried out by MSW management company of Shiraz municipality, 1000 tones wastes are transported to landfill every day and passed through a sorting system among which about 50%, are rejected. Table 3 shows the amount of rejected wastes from sorting system in 2013.

Table 3. The amount of rejected wastes from sorting system in 2013 in Shiraz (MSW Management Company of Shiraz municipality)

month	Percent
January	44.5
February	48
March	58.4
April	38.3
May	35.7
June	37.5
July	45.6
August	41.6
September	44.5
October	40.4
November	42.2
December	44.2

High Heating Value (HHV) is “the amount of heat released from combustion of a certain amount of fuel and assuming its combustion product water had returned to liquid state at the end of a measurement in which it took the latent heat of vaporization of product water into account”, while the Low Heating Value (LHV) is the amount of heat released under conditions that “the product water is still at vapor state and its latent heat of vaporization is not recovered” [6]. Table 4 shows physical analysis of rejected wastes from sorting system and their relevant LHVs. According to this table, LHV of theses wastes is equal to 11120 kJ/kg.

Table 4. Physical analysis of rejected wastes from sorting system and their relevant LHVs (MSW Management Company of Shiraz municipality)

Waste components	Weight (kg)	Percent of weight (%)	LHV of the targeted component (kJ/kg)	LHV of the targeted component in Shiraz wastes (kJ/kg)
Biodegradable wastes	32.2	22.88	1683	385
Paper and cardboard	0.8	0.57	15335	87.41
Carton	6.5	4.62	15549	718.4
Ferrous	1.2	0.85	603	5.12

metals				
Non-ferrous metals	0.3	0.21	603	1.26
Plastic	1	0.71	31669	224.85
PET	0.7	0.5	31669	158.34
Disposable container	2	1.42	31669	449.7
Glass	1.3	0.93	87	0.81
Hazardous waste	0.4	0.28	0	0
Non-recyclable wastes	22	15.63	6214	971.25
Closed packets	53.1	37.73	10042	3788.85
Different kinds of plastic bags	19.23	13.67	31669	4329.15
Total	140.7	100	-	11120

3. Incineration

In order to determine the adequacy of using incinerator as a waste to energy device, some terms like assisting fuel, potential of producing energy, potential of environmental pollution, investment costs, operation and maintenance costs, and economic assessment must be investigated.

3-1- Assisting fuel

According to world bank, in order not to add assisting fuel for incineration, LHV of wastes in each season and annual heating value must be more than 6000 and 7000 kJ/kg, respectively [7]. As LHV of the rejected wastes from sorting system of Shiraz landfill is 11120 kJ/kg, no assisting fuel is needed.

3-2- Potential of producing energy

The potential of producing energy from combustion of wastes is estimated by Eq. 1:

$$P = LVH * T * F \quad (1)$$

In which P is the amount of energy produced (kJ), T is the amount of burnt wastes (kg) and F is the efficiency of energy recovery system (percent) which is usually considered between 20 to 30%. Based on Eq. 1, the amount of daily energy produced from the combustion of 500 tons of rejected wastes of sorting system is equal to:

P= P=11120 kJ/kg *500000 kg*0.2=1112000000 kJ

As 3600 kJ is equal to 1 kilo watt hour, about 309000 kwh electricity can be produced.

According to the Ministry of Energy, the announced price of each kwh electricity which is produced by incineration system, is equal to 1 dime. Consequently, the nominal price of annual produced electricity is equal to:

309000 kwh*0.1 $/kwh *365= $11278500.

3-3- Potential of environmental pollution

Waste combustion causes some emissions in the air whose environmental costs must be considered (Table 5) [8].

Table 5. Environmental pollutions and their costs due to the combustion of wastes

subject	unit	Co_2	SO_x	NO_x	total
Amount of emission	mg/m^3	10	50	200	-
Environmental cost	$/ton	0.001	0.1773	5.1777	5.36
Environmental cost for daily 500 tons	$	0.5	88.65	2588.85	2678

Based on Table 5, the cost of environmental pollution caused by the combustion of wastes is about $977470 per year.

In addition to emissions to the air, wastes combustion makes some ash whose weight is 10 to 20% of the inflow wastes. So, daily 50-100 tons ash will be produced from waste incineration in Shiraz which can be either used in road construction or landfilled [9].

3-4- Investment costs

Investment costs include all costs of site selection, environmental assessment, and construction process [10]. These costs are different based on their producers which are shown in Table 6.

Table 6. Investment costs of different producers of incineration systems

producer	cost
Chinese producer	70000 US dollar for each ton of waste per day
Korean producer	100000 US dollar for each ton of waste per day
European producer (high costs)	237250 euro for each ton of waste per day

European producer (Martin GmbH)	171550 euro for each ton of waste per day

As Iran is a developing country which is located in the Middle East, using incinerators made by Chinese producers is recommended whose cost is about $70000 for each ton of received waste per day [9]. In conclusion, by using the incinerators made by Chinese producers for the combustion of 500 tons waste per day, the initial investment cost is about $35000000. In addition, the other investment costs for the construction of incineration system are about $1350000.

3-5- Operation and maintenance costs

Operation and maintenance costs include the costs related to paying workers' salaries, using chemical agents for the treatment of emission from chimney, used electricity, water and its transportation, landfilling residuals, and maintenance of buildings and machines that is considered about 7% of initial investment costs for Shiraz. In conclusion, annual operation and maintenance costs are about $2450000. In addition, assuming 30 years life time for buildings and machines, the costs of their depreciation, which is annually about $848000, must be considered in this part.

3-6- Economic assessment

According to the mentioned costs and interests, economic assessment of this project can be estimated using equation (2):

$$Wi = \left[\sum_{j=0}^{i-1}(1+r)^{j}(x-y-C)\right] - z(1+r)^{i} \qquad (2)$$

In which "Wi" is the amount of benefit in ith year, "r" is the bank benefit of money which is equal to 2%, "x" is the nominal price of annual produced electricity. In addition, "y" is sum of environmental pollution, and operation and maintenance costs, "z" is the investment cost, and "C" is buildings and machines depreciation costs.

According to this equation, by using incineration system for the combustion of rejected wastes from sorting system in Shiraz, the benefit of the project is about 280 million dollars after 30 years.

4. Conclusion

As about 1000 tons MSW are generated in Shiraz and 75% of them are landfilled in this city, a large amount of land is required and a lot of money is paid without any economic benefits.

Another option for MSW management in this city, is incinerating the rejected part of sorting system with LHV equal to 11120 kJ/kg. Because of producing electricity from incineration of MSW, 11278500 dollars can be earned annually. On the other hand, incineration causes some environmental pollution, investment, operation and maintenance costs which might make the project unprofitable. By doing an economic assessment, it is obvious that the benefit of the project is about 280 million dollars after 30 years. In conclusion, by using incinerator for Shiraz MSW instead of landfilling, not only it saves land, but also it is economically advantageous.

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5. References

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