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Going for Waste to Energy in Developing Countries

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Abstract

Municipal solid waste (MSW) is a global environmental problem. Its quantity is increasing with corresponding increase in population. Safe disposal of MSW is a big challenge for municipal authorities. One way of disposal of MSW is in landfill sits and the other is to make its beneficial use as fuel for power generation.

MSW is easily available in abundance and is a cheap source of energy for power generation. Solid waste incinerator can remove up to 99.9999 percent of all toxins from their emissions and as such are no more harmful to the environment; in comparison MSW landfills emit methane-gas, and leachates that are hazardous for environment and ground water.

This research study has examined the possibility of waste to energy project for capital city of Pakistan, and has carried out its technical and financial feasibility analysis. This technically feasible and cost effective project will not only solve the MSW disposal problem, but would improve the environment of the city along with providing electricity and saving precious foreign exchange used for import of fuel.

Keywords

Municipal Solid Waste, Waste to energy, Power generation, garbage incineration, Refuse Derived Fuel

1. Introduction

Municipal solid waste (MSW) is mostly generated by human, it is the surplus and worthless stuff not needed at their homes, offices, factories and hospitals etc. MSW quantity is increasing with corresponding increase in population. Safe disposal of MSW is a big challenge for municipal authorities. MSW is mostly being dumped away from cities without any treatment. There are many ways of making beneficial use of MSW along with its disposal with less or no damage to environment. It is now possible with available technologies to remove toxins up to 99.9999 percent during energy recovery process (Khanjan et al. 2014).

MSW is easily available in abundance and is a cheap source of renewable energy for developing countries. Using MSW as energy source would not only solve the garbage disposal problem but would also have a positive impact on the environment. It has been examined in this study if waste to energy project can be executed in capital city of Pakistan, and technical and financial analysis have been carried out to support the decision making process. Waste to energy project will (not only solve the MSW disposal problem, but would also save the precious land used for landfill along with improving the environment of the city and saving precious foreign exchange used for import of fuel.

1. Study objective and scope

The purpose of this study is to find out, if this project is technically and financially workable and would it be worth to invest on this project ? What measures are required to be taken to make it possible to execute the project?

2. The Project Environment

2.1 **Organizations involved**: (i) Municipal Corporation Islamabad (ii) Private sector/technology and service provider (iii) Islamabad Electric Supply Company (IESCO)

2.2 Input/output

Input would be MSW/garbage and output would be electricity and recyclable material

2.3 System interaction

It would be dependent on the garbage collection system of Municipal Corporation Islamabad (MCI) and its delivery to the power plant.

2.4 Physical environment

Sufficient spaces and locations are available around Islamabad, where the plant can be established. There will no emission of foul gases during incineration; therefore, the environmental problems will not arise.

2.5 Functional objectives

In case, the project is technically and physically feasible. Arrange a financer and take up the matter with MCI for an agreement to provide garbage free of cost and obtaining/lease a piece of land for setting up the power plant. Environmental friendly disposal of MSW is also a big objective.

2.6 Performance objectives

Utilizing 750 M. ton MSW per day and generating 18750 kwh electricity, i-e 25 kwh of electricity is produced from each ton of garbage processed at Energy Plant in Baltimore Maryland. According to a Chinese report they are producing 225 Kwh per ton of RDF (refuse derived fuel) (Luhe and Cugu-2010). According to Florida State University the electricity production is 500 Kwh per ton of MSW (Demers-2009). We have used the most conservative estimate of 25 Kwh.

3. Assumptions and constraints

i. MCI would agree to provide all the generated MSW free of cost. (ii) Financer would be available (iii) No problem in transfer of technology (iv) IESCO will purchase the power produced, at a reasonable price

4. Methodology

The information available in the literature and primary data from the local organizations and MCI has been explored. Ground realities have also been analyzed to find out a technically and financially feasible project.

5. Evaluation criteria

Cost comparison has been carried out to know if energy produced by MSW is compatible with its close competitor i-e Coal. The cost of electricity produced has also been estimate along with Return on Investment (ROI), and payback period to arrive at a calculated decision.

6. Literature Review

6.1 **Availability of raw material for Waste to Energy project**

According to a brief/report of ministry of environment Pakistan (2008), the rate of waste generation on average in major cities of Pakistan from all type of municipal controlled areas varies from 0.283 kg/capita/day to 0.613 kg/capita/day or from 1.896 kg/house/day to 4.29 kg/house/day in all the selected cities. Islamabad city is generating about 0.5 kg per capita/day i-e 1000 M. tons of garbage (MSW) per day out of which about 750 m ton is collected. The major source of waste generation in Islamabad is from households and institutions, commercial establishments including organized markets, wholesale establishments, weekly markets, retail markets, health care facilities and slaughterhouses. The garbage mostly comprise of paper, plastic, polythene bags, glass, metal, ceramics, vegetable/fruit peals, bones and cloths etc. more than 90% garbage is organic material and combustible.

Table-1 Composition of MSW (Ministry of Environment-2008)

MSW Composition Item	1999 Study Percent	Decomposable Percent	EPA 1999 Generation
Paper	34.2%	34.2%	38.1%
Plastic	11.0%	0%	10.5%
Metals	4.4%	0%	7.8%
Glass	2.7%	0%	5.5%
Organic Materials	27.3%	17.2%	28.3%
Other Waste	18.3%	2.4%[2]	6.6%
Problem Materials	1.8%	0%	3.2%
HHW/HW	0.3%	0%	0%
	100%	53.8%	100%

Local available MSW contains moisture between 25 to 50% depending on the season and ambient temperatures. Technology is now available to tackle this problem and use it for power generation.

Table-2 Typical Composition of Solid Waste in Pakistani Cities (Ministry of Environment-2008)

Composition	%
Food Waste	8.4% to 21 %
Leaves, grass, straw, Fodder	10.2 % to 15.6 %
Fines	29.7 % to 47.5 %
Recyclables	13.6 % to 23.55 %

Almost 1/4th of the MSW comprise of recyclable material, it is due to this reason we see lots of scavengers roaming around garbage dumps in search of valuable materials.

6.2. Waste to energy technologies

Several types of incineration technologies are available today, and the most widely used are:

6.2.1 **Mass burning incineration**—with a movable grate

The mass burning technology with a movable grate has been successfully applied for decades and was developed to comply with the latest technical and environmental standards. Mass burning incineration can generally handle municipal waste without pre-treatment on an as-received basis (Thomas 2014). According to the World Bank report (1999) mass burning technologies are generally applied for large-scale incineration of mixed or source-separated municipal and industrial waste.

This technology is being successfully and extensively used in USA, Germany, Netherlands, France, Japan, Sweden and many European countries for last 25 years. According to Pak, (2006) Japanese are disposing off their 75% garbage through incineration, power generation facilities are implemented in only 20.5% among 1347 garbage incineration plant in Japan (in 2004). Garbage incineration reduces the volume of MSW by more than 90% due to which a very little space is required for disposal of ash in landfill.

6.2.2 **Rotary kilns**
Compared to movable grates the rotary kiln incineration plants have a smaller capacity and are mostly used for special types of waste unsuitable for burning on a grate, such as various types of hazardous, liquid, and infectious waste

6.2.3 **Fluidized bed incineration**,

It is still at the experimental stage and should therefore not yet be applied

6.2.4 **As a preheating support process**
In this method low temperature steam produced at the garbage incineration plant is super-heated by using high temperature gas turbine exhaust gas, and is used to drive a steam turbine generator for generating electric power with relatively high total efficiency (Pak-2006). Multiple fuels are used in this system.

6.2.5 **Ultrahigh temperature gasification**.
This distillation process involves the application of intense, indirect thermal energy in the absence of oxygen which reduces the material to a combustible gas and a non-hazardous, non-leachable inorganic material. This fully integrated system which combines both waste disposal and recycling, creates no harmful residues or atmospheric emissions, provides an environmentally friendly solution of MSW treatment. The combustible gas is used to generate electrical power (Pyromex-2014).

6.2.6 **Gasification and pyrolysis**
These are some of the most effective waste to energy technologies available currently. These two technologies can be performed together to maximize the cost effectiveness. Pyrolysis needs an outside heat source, and this is supplied by the gasification process, making both processes together self sustaining. This reduces the cost of the process, making them both more cost effective. Waste to energy in this manner can create several forms of energy (Thomas 2014).

6.2.7 **Anaerobic digestion**
The waste is put in specially constructed digesters, and no oxygen is allowed in. It breaks down the waste at much faster rate, releasing greenhouse gases including large amounts of methane. This process can also create heat from the large amounts of microbial activity as the biomass is decomposing. It is a slow process used for small quantities of MSW (Thomas 2014).

6.2.8 **Fermentation**
This waste to energy technology can take biomass and create ethanol, using waste cellulosic or organic material. In the fermentation process, the sugar in the waste is changed to carbon dioxide and alcohol. Normally fermentation occurs with no air is present. Esterification can also be done using waste to energy technologies, and the result of this process is biodiesel. The cost effectiveness of esterification will depend on the feedstock being used, and all the other relevant factors such as transportation distance, amount of oil present in the feed stocks, and others (Thomas 2014).

7. **Technical Analysis**

Moisture content of city MSW is more than 25%, therefore it will require bringing down the Moisture content below 15% for making it easily burnable, otherwise energy recovery will be comparatively on lesser side. It will require installation of a kiln and use heat generated with burning of gas, RDF or using hot flue gases of plant. Moisture can also be reduced by dumping MSW in open sun light for few hours in hot weather before brining it to plant.

In order to resolve the Low Heat Value (LHV) problem, Dezhen (2007) suggested to use aged MSW from landfill sites along with fresh MSW. The aged MSW from the garbage dumps will need mechanical excavation before re-treatment and re-utilization; then the aged MSW undergo separation steps to separate combustibles from soil, stones, glass, bricks, etc. When using combustibles to produce RDF, they must be shredded to let blending combustibles and additives easier. Dezhen (2007) also suggested to use additives to help control acidic gas emission.

Around 70% of plastics in fresh MSW is polyethylene and polypropylene and 40% of them can be easily separated for re-utilization before putting the MSW in the furnace. If plastics were separated, the LHV would be even lower. In practice auxiliary fuel such as oil, or coal would be needed for stable and complete combustion (Dezhen-2007).

Since there is about 23% recyclable material in the MSW, therefore, sorting of recycle material before incineration will be beneficial for recovery of project cost. Recyclable material can be retrieved by installing a separator in between kiln and the furnace hopper.

8. Financial feasibility

Table-3 Comparison of calorific value of RDF with its competitors (Shahid & Sohail-2013)

S #	Fuel	Calorific value kcal/kg	RDF equivalent (1kg fuel = kg RDF)
1	Coal (lignite)	4400	1.47
2	Furnace oil	10,000	3.33
3	Natural gas	13000	4.33
4	RDF	3000	1.00

If we compare the energy produced by MSW with its closest competitor "Coal" it reveals that 1.00 M Tons of Coal is equivalent to 1.47 M Tons of RDF. In Islamabad. The coal costs about Rs. 6200.00 or (US$ 55.85) per Metric Tons, whereas RDF costs according to Table-5 works out to about Rs. 859.52 per M. Ton. It means that RDF amounting Rs. 1263.50 can generate heat equal to coal costing Rs. 6200.00 with a saving of Rs. 4936.50 or 79.62 %.

Table-4, Material and Energy Consumption during Making RDF from Aged MSW (Dezhen-2007**)**

Step	Aged MSW mining Separation	shredding and blending	RDF production
Energy & material consumption	Oil: 0.7kg/ton aged MSW	Electricity: 0.75kwh/ton aged MSW	Electricity: 0.7kwh/ton RDF CaO: 80kg/ton RDF

Table-5, Cost of making RDF from aged MSW (Shahid and Sohail -2013)

In put	Qty	Unit	Rate	Amount Rs.
Oil	0.7	Kg	55	38.5
Electricity	1.45	Kwh	14.5	21.02
CaO	80	Kg	10	800.00
Total cost of making RDF from MSW per ton			Rs. US $	859.52 7.74

Table-6, Cost estimate of the project:

	1. buildings, plant & machinery	Amount in m US$	
A	Civil works	LC	FC
	Incineration & power generation	0.200	
	land filling	0.200	
	composting	0.050	
	Sub total	0.450	
B	Foreign machinery		12.500
	Land filling equipment		1.500
	Incineration & power generation equipment composting		1.350
	sub total		15.350
C	Insurance, clearance, inland freight etc @ 0.75%	0.119	
D	Erection @ 0.75%	0.119	
E	Financial charges during construction	1.000	
F	Contingencies @ 1%	0.158	
	Total (a to f)	1.845	
	Grand total		17.195
	2. Furniture and fixtures		
A	Furniture & fixtures	0.025	
B	Vehicles	0.075	
	Total cost of fixed assets (1+2)	17.295	
	O&m cost of plant @ 2% per annum	0.346	

8.1 **Annual revenue**

i. Production of electricity for sale assuming a plant factor of 0.7, the energy produced per annum =18750x330x24x0.7=103.95m kwh

Revenue/year with tariff rate @10 cent / unit = 10.395 million US$

ii. Recycled ferrous metal

Daily generation = 3 ton @ US$ 225/ton.

Revenue=3x330x225=0.223 m US$
iii. Recycled plastic material
Daily generation = 20 ton
Revenue @ US$ 105/ton
= 20x330x105 = 0.693 m US$
iv. Total annual revenue = 11.311 m US$

8.2. **Annual Return on Investment**

Capital = 17.295 m US$
Revenue = 11.311 m US$
Expenditure = 0.346 m US$
Depreciation = 1.023 m US$
Financial gains= 9.942 m US $
ROI = 57.48%

8.3. **Pay Back period** < 2 years

9. **Steps required to materialize the project execution**

- Induction of Consultants for preparation of design, documentation and supervision of the project
- Preparation of Environmental Impact Assessment (EIA) report and getting it processed for approval from Pakistan Environment Protection Agency
- Commitment and decision by MCI that MSW will be collected and supplied to the project using existing transportation arrangements free of cost
- Selection and approval of the technology and equipment for the project on the basis of report of consultants
- Approval from Gas supply company to provide required fuel gas for the project
- Human resource with appropriate training
- Capital of 17.295 US$ for a plant capacity to handle 750 M tons of MSW for producing 18750 kwh electricity.
- Agreement with intended consumer (IESCO) to purchase the electricity and make payments on monthly basis

10. **Findings**

- Furnace oil cost / ton has increased from Rs. 2,900 in 1994 to Rs. 45,000 (US$ 405) with an increase of more than 10 times during the last twenty-four years, therefore it is extremely essential to use alternative fuel source, which is easily available in the form of MSW.
- The MSW of Islamabad contains moisture between 25 to 50%, which would not be helpful for proper incineration. It can be used with little work on it.
- The raw material is easily available in abundance and certainly would further increase in future
- The project is technically & financially feasible
- Non-combustible recyclable material can be retrieved from the residue of the plant, which has a market value.
- Plastic material however will get burned because there is no sorting system in the mass burning incineration system used by industrialized countries.
- The MSW volume gets reduced by more than 90% therefore comparatively very small land fill site would be required. The ash is also useable in road construction projects for stabilizing earth.
- The project would have a positive effect on the cities environment
- MCI's assistance would be required to supply the MSW free of cost and CDA will provide a piece of land on lease for setting up the power plant

- Power generation prices from MSW are competitive as compared to its close competitor coal
- There are many potential customers of electricity, like IESCO, CDA, local industry and private housing schemes etc
- Overall impact of project is positive

11. Recommendations

- Put up a plant with a capacity of 750 M tons per day
- Preferably two production lines be established, each having capacity around 375 M. Ton per day.
- Devise a mechanism to reduce the moisture of MSW to at least 15%, by preheating using the flue gases or by drying it in open sunlight.
- There is plenty of recyclable material in MSW (between 13 to 24%); it should be sorted out (especially metals, glass, plastics, rubbers, and un-combustible materials) before putting it in receiving hopper.
- The project cost can be invested by MCI, or the investor may be asked to build, operate own and transfer (BOOT) with some concessionary period.
- The terms of reference must include the condition with the understanding of MCI and CDA that MCI shall ensure supply of MSW to power plant as per requirements free of cost and CDA shall lease out an approachable piece of land for setting up the power plant.
- Garbage disposal charges may also be levied on the garbage generators at some appropriate and proportionate ratio that may be collected by MCI to recover the project cost.

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