Capacity Estimation of Power Generation from MSW of Peshawar City

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ABSTRACT

Grim issue of Electricity shortages in most of developing countries leads to explore the potential in renewable and economical sources of energy. Power generation through Waste To Energy (WTE) Plants is an effective way to deal with the problems of MSW management and electricity shortages in densely populated cities of the world. In this paper, capacity estimation of Power generation from Municipal Solid Waste (MSW) of Peshawar city through Solid Waste Fueled Power Plant (SWFPP) is analyzed. For effective estimation of power generation through WTE plant, a detail study about estimation of Municipal Solid Waste of Peshawar city, composition and characteristics of collected waste, appropriate conversion technology; heat generated from it and ultimate power generation is discussed.

Keywords
Renewable Energy, Waste to Energy, Electricity, Power generation, Pakistan Power crisis, Municipal Solid Waste Fueled Power Plant.

1. INTRODUCTION
Life of every human being is highly dependent on energy, it is an indispensable necessity and plays crucial role for the achievements of basic needs such as water, food, shelter, education and health care. Energy consumption is a key indicator for identifying the degree of Social development of an area.

Rapid population growth in developing countries has accelerated the pace of urbanization which has resulted in many environmental problems including the significant problem of Municipal Solid Waste (MSW) management or treatment [1-4]. In 1999 European Union (EU) parliament approved an act which bounds every member country to stop disposal of MSW without proper treatment with effect from 2005 [5]. Several practices are used to make a usable work of MSW such as making compost [6], landfill gas to energy [3], power generation by incineration of waste and Plasma Gasification [7].

Power generation from MSW by Waste To Energy (WTE) power plants can be a good choice for countries like Pakistan which is the sixth populous country but facing major crises of its history in terms of power shortages, the problem is evident from Pakistan energy consumptions which is 0.037% of worlds total energy utilization with the population of 2.56% of world population [8]. The major reason of Pakistan's power crises includes demand and supply gaps, line losses, more dependency on oil based power plants and ultimately high cost of electricity. Total Power generation of country comprises 36% from imported oil, 32% from hydro power plants, 27% from natural gas, and 5% from nuclear and coal. One of the main cause of higher per unit price of electricity is substantial dependency on imported oil in power sector as in 2011 the country oil imports were 40% of total imports which

took the trade deficit up to 12% [8, 9]. In such circumstances SWFPP solid waste fueled power plant which uses MSW a renewable resource as a fuel can be considered as an adequate resource in the energy mix of the country to bring down the average per unit cost of electricity.

The population and urbanization growth emanate the problems of MSW management and electricity shortages and both the problems can be minimized by converting municipal solid waste to electricity by the help of SWFPP.

For the effective estimation of the capacity of MSW fuelled Power Plant the precise estimation of MSW and heat generated is required as shown in functional block diagram of Figure 1.
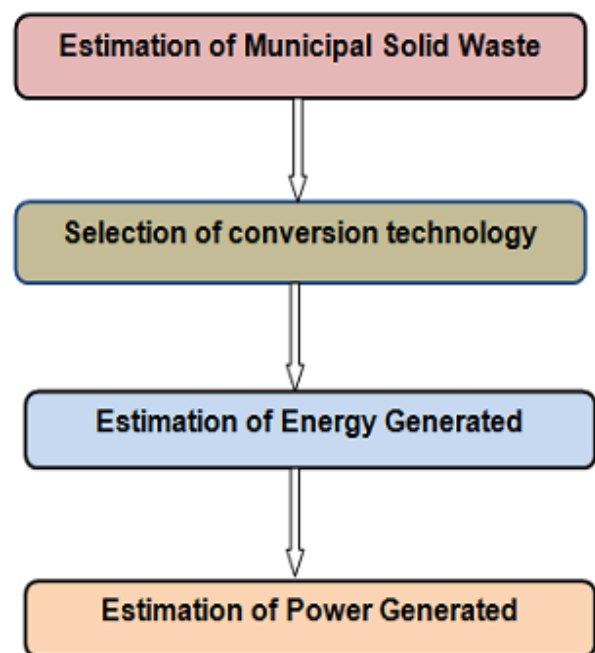

Fig 1: Block diagram of steps involved in estimation of power generation from MSW.

The following analysis has been done in this research document,

- The MSW per day of Peshawar city is estimated through the transportation capability and schedule of concern organizations.

- 5kg samples of MSW have been collected from each of 12 different locations of the city for the analysis of composition of waste.

- Four different technologies of power generation has been discussed and one of them is proposed on the basis of economical and operational aspects.

- The final calorific value has been calculated on the basis of composition of MSW of Peshawar city. The capacity of Power plant has been calculated as 12.4 MW on the basis of final calorific value.

- A suitable site has been proposed on the basis of certain constraints and is shown by the help of Google maps in Fig. 2.

2. ESTIMATION OF MSW

Peshawar is the capital city of Khyber Pukhtoonkhwa Province formally known as North West Frontier Province (NWFP) and lies between 33° 44′ and 34° 15′ north latitude and 71° 22′ and 71° 42′ east longitude. According to 1998 census the population of the city was approximately 2,019,118 with an annual growth rate of 3.5 percent. According to statics of provincial government currently the population of Peshawar is approximately 3.50 million as shown in Table 1.

Table 1. Area and population of Peshawar city

Name of City	Area in Km2	Population of City
Peshawar	1256 Km2	(3.50 million)

The mentioned population does not include the count of afghan refugees and the count of population came from other areas for education, jobs etc and include only the registered citizens of city.

2.1 MSW Collected Per Day

Daily waste collection of the city is calculated by the analysis of transportation capability and schedule of Municipal Corporation Peshawar (MCP) as shown in Table 2. Mainly three organizations involved in collection of MSW of city are MCP, Cantonment Board Peshawar (CBP) and Peshawar Development Authority (PDA).

Total amount of MSW estimated from Table 2 is 1331 ton, the waste generation rate can be calculated as,

$$\frac{\text{Amount of MSW collected per day}}{\text{Population of the concerned area}}$$

= 1331 tons / 3.50 million,

= 0.38 Kg per person per day

Waste generation rate is less than that of Chennai India having 0.5 - 0.65 Kg/person/day [3] and is slightly more than that of Chittagong Bangladesh [1]. One of the major parameters of waste generation rate is the extent of development of area. In developed areas the waste generation rate can reach as high as 2.75 to 4.0 Kg per person per day [6]. Routing of MSW to storage points is a major element of municipal solid waste management in urban cities where only the collection systems of waste takes about 85 percent of overall expenses and disposal takes only 15% [10]. The organizations involved in the collection of MSW of city does not have much efficient systems of waste collection and management and actual figures of per capita MSW generation may be more than 0.38 Kg per person per day.

Table 2. MSW collection capability of Municipal Corporation Peshawar

S. no	Type of Vehicle	Count	MSW carrying ability of each vehicle in tons	Trips per day	Total
1	Containers	131	5.0	1	655 tons
2	Tractor trolley	30	3.5	3	315 tons
3	Pickup trucks	28	1.0	3	84 tons
4	Mini Tractor trolley	15	2.0	3	90 tons
5	Trucks	23	4.0	2	184 tons
	Total				1331 tons

2.2 Composition of Collected MSW

MSW is mainly composite of food wastes (includes vegetables and fruits), paper products, wood, wood straws and wood materials (chips board, card boards), plastics and packing materials of different utility items, textile, rubber etc. Some of the waste materials can be recycled to make new goods but the majority of the remaining are in composite structure and cannot be reused or recycled. For the analysis of MSW of Peshawar a 5 Kg sample of MSW is collected from twelve different areas of the city and data is tabulated in Table 3. Results shows a major share i.e. 31.9 % of the MSW of Peshawar city consists of fruits and vegetable wastes. Second major share is of plastics which consist of 20.4 % of total MSW. Paper products consists 13.1 %, wood straws and tree trimmings consists 12.3%, textile consists 8.7% and leather and rubber consists 4.1% respectively. 9.1% of city MSW consists of non flammable materials which includes clay, debris etc.

Table 3. Data of composition of MSW in different areas of Peshawar

S. no	Date	Location	Fruits & vegetables	Plastics	Paper products	Wood, Tree Trimmings and card boards,	Textile	Leather & Rubber	Clay, dabre ceramics and other non flammable materials
1	22/09/2014	Qisa khwani Bazar	35	19	7	6	12	4	17
2	22/09/2014	Gul Bahar	33	27	12	11	5	5	7
3	22/09/2014	Chowk Yadgar	50	20	10	8	5	3	4
4	22/09/2014	Akhon Abad	26	20	8	20	8	4	14
5	22/09/2014	Hayatabad	28	21	13	13	9	4	12
6	22/09/2014	Govt college Peshawar	30	23	15	10	8	6	8
7	22/09/2014	Dabgari Garden	32	30	14	5	11	6	3
8	22/09/2014	Old Tehsil	35	21	13	3	7	3	12
9	28/09/2014	University Town	23	17	18	19	8	3	11
10	28/09/2014	Board Bazar	38	17	13	11	10	5	6
11	28/09/2014	Peshawar Cantt	24	16	16	20	13	3	8
12	28/09/2014	Peshawar University	29	14	18	21	8	3	7
		Composition of MSW in percentages	31.9	20.4	13.1	12.3	8.7	4.1	9.0

3. WASTE TO ENERGY CONVERSION TECHNOLOGIES

Different Waste to Energy (WTE) conversion technologies are in practice for power generation from MSW are as follows.

- Pyrolysis: The process in which the thermal decomposition of Municipal Solid Waste occur in the absence of air is called pyrolysis

- Conventional Gasification: In this process syngas is produced from Municipal Solid Waste in the presence of limited amount of air or oxygen

- Plasma Arc Gasification: In this process a hot ionized gas is produced by the decomposition of organic compounds by the help of plasma arc produced by plasma torches [11]

- Incineration: The process in which the MSW is burned in the presence of air or atmosphere, the process is also known as conventional Mass-Burn [12]

Amongst the four discussed technologies the pyrolysis and conventional gasification requires certain pylothetic reactions and are generally slow processes and are not desirable in case of Power generation from MSW. The plasma arc gasification has better efficiencies but is having high capital cost and plasma torches maintenance makes it more complex moreover the cost of per unit generated energy in case of Plasma gasification is around 10 cents per KWh where in case of mass-burn or incineration is around 5 cents per KWh [7]. Incineration or conventional mass-burn is less efficient in terms of power generation but is most simplest and convenient way of power generation from MSW.

4. ESTIMATION OF HEAT AND POWER GENERATION

Each entity of Municipal Solid Waste is having a certain heating value in its dry form. Heating value of each entity is shown in Table 4 in KJ/Kg and in Btu/lb [2, 13]. On the basis of average heating values of each entity of MSW from Table 4, final calorific value of MSW is calculated in Table 5. MSW is having different moisture contents in its different constituents, area demography and weather conditions also have certain effects on moisture levels in constituents of waste. Average value of the moisture contents of each entity is considered from World Bank Technical Guidance Report and is given in Table 5 [2]. The percentage composition of MSW is taken from Table 3. After the deduction of moisture contents, the dry amount of MSW calculated in Table 5 is 40.9% of total MSW collected. The final heating value of each constituents of Municipal Solid Waste in KJ/ Kg is calculated by the relation,

Average calorific value from Table 4 $\times$ Dry MSW in % from Table 5

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100

The final heating value of MSW is obtained as 9841.0 KJ / Kg by adding final calorific values of each constituents of waste from Table 5.

Table 4. Calorific values of different entities of MSW [2, 13]

		Calorific values of dry MSW constituents		Selected average calorific values	
S. no	**Constituent**	**kJ / kg**	**Btu / lb**	**kJ / kg**	**Btu / lb**
1	Plastics	25,586-41,868	11 ,000-18,000	33,959.6	14,600
2	Food waste	18,608-20,934	8000-9000	19,538.4	8400
3	Paper products	16,282-18,608	7000-8000	17,677 .6	7600
4	Wood	18,608-20,934	8000-9000	19,305.8	8300
5	Leather, rubber	23,260·37,216	10,000-16,000	26,283.8	11,300
6	Yard waste	15,119-17,445	6500-7500	16,979.8	7300
7	Textiles	18,608	8000	18,608	8000

Table 5. The final calorific value of Peshawar city waste

	Fruits & vegetables in %	Plastics in %	Paper products in %	Wood, Tree Trimmings and card boards in %	Textile products in %	Rubber and Leather in %	Metals, Clay, and nonflammable substances	Total
Composition of each entity of MSW in%	31.9	20.4	13.1	12.3	8.7	4.1	9.0	100
Moisture in each entity of MSW in %	20.7	63.2	47.4	59.8	63	59.8	0	---
Dry MSW in %	6.6	12.9	6.2	7.3	5.5	2.4	0	40.90%
Final heating Value of MSW	1290.9 KJ / Kg	4381.9 KJ / Kg	1096.3 KJ / Kg	1414.2 KJ / Kg	1016 KJ / Kg	641.8 KJ / Kg	0	9841.0 KJ / Kg

Combustible portion of Municipal Solid Waste of Peshawar city is 40.90 percent from Table 5 and final heating value is calculated as 9841.0 KJ / Kg.

The amount of combustible MSW in tons can be calculated as

$$(40.9 \times 1331 \ tons)/100$$

= 544.370 tons

Thermal systems used in WTE plants have the efficiencies of about 20 % [1].

Considering the 544.370 tons of combustible MSW, 9841.0 KJ / Kg of calorific value and 20 % of thermal efficiency, The total energy generated per day can be calculated as,

544370 Kg / day $\times$ 9841.0 KJ / Kg $\times$ 0.20 = 1071.44 GJ/day

To calculate the capacity of power plant from 1071.44 GJ/day,

1 MJ / Second = 1 MW of Power,

$$\frac{1071.44 \ GJ}{86400 \ sec} = \textbf{12.4 MW}$$

Hence the capacity of MSW fueled Power Plant for city of Peshawar is calculated as 12.4 MW.

5. LOCATION OF POWER PLANT

Selection of appropriate location for MSW fueled Power Plant is subject to certain constraints which includes the distance from city centre, accessibility from the city, distance from nearest power hub (grid station) etc. The proposed site for Power Plant is shown in Fig. 2 by the help of Google map and is about 13 Km away from city centre, 07 Km away from 1st dumping point (Bahadar Kaley), and 06 Km away from second dumping point (Shahid Abad). Proposed site is about 06 Km from 500 KV main Grid station which provides electricity to whole of city.

Real Genetic Algorithms is the most useful tool for selection of optimal path for MSW collection and supply to the proposed site efficiently and effectively[10].
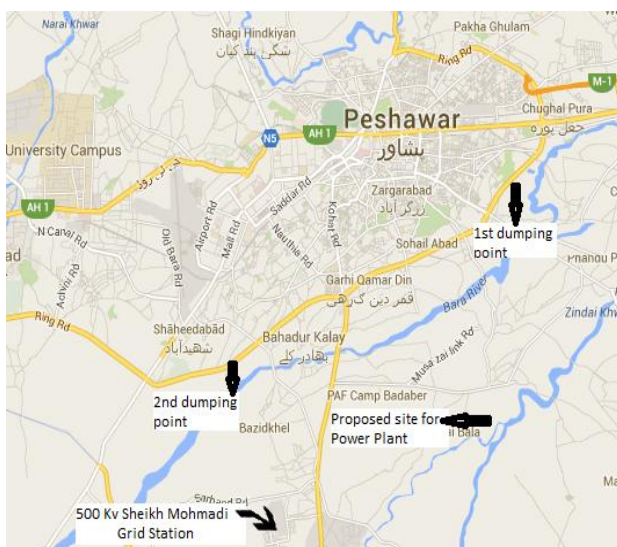

Fig 2: Google Map of Peshawar City presenting both of the existing dumping points, 500 KV grid station and proposed site for power plant.

6. CONCLUSIONS

Capacity Estimation in this document is calculated on the basis of MSW collection Capabilities of Municipal Corporation Peshawar. The capacity can be improved by improving the waste collection system of concern organizations.

The main factors of Electricity shortages and power crisis in Pakistan are demand and supply gap and high cost of per unit of electricity due to greater dependency on imported oil based power plants. This research can utilize to build SWFPP to minimize the demand and supply gap. Similar estimation can be worked out for other major cities of the country like Karachi, Lahore etc having populations twice trice of Peshawar.

The current national average per unit cost of electricity of Pakistan is 14 cents per KWh [14], where the per unit cost from incineration based SWFPP is around 5 cents per KWh [reference] which is quite less as compare to national average and hence can be utilized to reduce the national average cost of electricity.

SWFPP projects have positive Social Return on Investment (SROI) and are 'Triple P' projects which have profitable status and have positive impact on people and planet [15]. Installation of SWFPP with appropriate emission systems will be helpful in decreasing pollution level of urban cities as majority of uncollected or discarded MSW is burned through un professional ways in open air causing unpleasant effects on the overall environment of the city.

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