FEASIBILITY OF POWER GENERATION FROM BANGKOK MUNICIPAL WASTES

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ABSTRACT

Bangkok municipal area generated about 5,500 M tons of solid wastes per day in 1991. Bangkok Metropolitan Administration is however able to collect only about 4,200 M tons/day and dumps them at three disposal sites in Nongkham, On-Nooch and Ram Indra sub districts of Bangkok. Two compost plants have been recently renovated and set up and now operate with combined capacity of 1000 tons of municipal wastes per day.

Municipal wastes consist of commercial refuse, industrial wastes, institutional wastes, residential wastes and market wastes. On the average, municipal wastes comprise 85.3% combustible, 8.6% non-combustible and 6.1% miscellaneous components. The combustible components, on the average consist of 58.5% moisture, 13.3% ash and 28.2% combustible content and the net heating value is about 16.1 MJ/kg, dry basis.

As about 1000 tons of the Bangkok municipal wastes are consumed in the compost plants, more than 4000 tons of the wastes are available as fuel for electricity generations. It is assumed that four power stations would be set up, each with a capacity of 1000 tons of the municipal wastes per day.

The feed rate of the municipal wastes to each of the proposed plant is 14.7 tons/per hour of combustible contents, dry basis. With a superheated boiler rated at 80 bar, 450 C, each proposed power plant should be able to generate about 8.33 MWe. The combined generating capacity of the four power plants is therefore 33.3 MWe.

The financial analysis including the cost of the wastes processing shows that the proposed power stations would be able to generate electricity at 0.83 B/kWh and have a pay-back period of 4-5 years and IRR of 24.9%. However, if the total cost of the fuel is excluded, the cost of electricity would decrease to 0.70 B/kWh. The pay-back period would also decrease to 3-4 years and IRR would increase to 28.2%. On the otherhand, if the total cost of the fuel is taken into account, the proposed power station would not be financially feasible.

KEY WORDS

Feasibility, power generation, municipal wastes.

INTRODUCTION

Twenty four districts of the Bangkok Metropolitan Administration cover about 1,550 square kilometers and has a registered population of about six millions. Solid waste production in Bangkok increased from 4,500 tons per day in 1987 [1] to about 5,500 tons per day in 1991. Rates of waste production per capita vary from about 1.77 kg/capita-day in highly developed central areas of Bangkok to about 0.45 kg/capita-day in rural districts.

Four types of collection vehicles are in use, namely side-loader non-compaction trucks, rear-loader compaction trucks, container-hoist trucks and standard dump trucks. Wastes are hauled directly from the collection points to regional disposal facilities. The average haul distance is about 48 km [1] and the average collection cost is about 10 USD/ton.

The BMA is currently able to collect about 4,200 tons/day and dump them at three disposal sites in Nongkham, On-Nooch and Ram Intra. Two compost facilities have been set up and operate with a combined capacity of about 1000 tons/day. The cost of compost produced is approximately 75 USD/ton.

Disposal of waste by dumping is rather unhygienic and can cause considerable damages to environment such as underground water, canals, etc.. Waste incineration is a better option and power can be generated as a by-product. Singapore has already operated waste incinerators with a power generating capacity [2].

WASTE CHARACTERISTICS

Municipal wastes consist of commercial refuse, industrial wastes, institutional wastes, residential wastes and market wastes. On the average, municipal wastes comprise 85.3% combustible, 8.6% non-combustible and 6.1% miscellaneous components.

The combustible component consists of paper, garbage, textile, wood and grass, plastic, rubber and leather. The non-combustible component comprises ferrous metal, non-ferrous metal, glass, stone and ceramics.

The combustible component, on the average consists of 58.5% moisture, 13.3% ash and 28.2% combustible content and net heating value is about 16.1 MJ/kg, dry basis.

FEASIBILITY OF POWER GENERATION

The Electricity Generating Authority of Thailand recently issued an announcement [3] on the Purchase of Power from Small Power Producers. Feasibility of power generation from municipal wastes should therefore be seriously considered. For this study, technical, economic and financial assumptions are given in Tables 1 and 2. The total cost of fuel consists of the costs of waste collection [1] and waste processing. The system capital cost does not include the cost of emission control from the boiler [4].

As about 1000 tons of the Bangkok municipal wastes are consumed in the compost plants, more than 4000 tons of the wastes are available as fuel for electricity generations. It is assumed that four power stations would be set up, each with a capacity of 1000 tones of the municipal wastes per day.

In a previous study [5], the efficiency of a bagasse-fired boiler was found to be only about 60% since the bagasse contained a high moisture content of about 50%. In this study, as the municipal waste also contains a very high moisture contents, the boiler efficiency of 60% is therefore assumed.

Table 1. Technical Assumptions

(1) General Characteristics	
Proposed plant capacity	1000 tons of wastes/day
Or	41.7 tons/hr
Feed rate of the dry combustible component	14.7 tons/hr
Heat input rate	237 GJ/hr

(2) Boiler Characteristics

Delivery pressure	80 bars
First law efficiency	60 %
Feed water temperature	120 C
Steam temperature	450 C

(3) Turbo Generator

First law efficiency	85%
Exhaust pressure	0.10 bar
Exhaust condition	dry saturated

Table 2. Economic and Financial Assumptions

System capital cost (1991)	1500 USD/kWe
Useful life of the system	20 years
Total fuel cost :	13 USD/ton
Comprising : waste collection	10 USD/ton
waste processing	3 USD/ton
Debt/Equity ratio	75:25
Return on equity (after tax)	25%
Discount rate (weight)	17.5%
Cost of debt	15%
Tax rate	30%
Salvage value	5%
Repayment of debt	10 years, equal installments
Depreciation	10 years, straight line method
Buy-back rate	1.10 Bath/kWh
Escalation rates (%)	

	1991/92	1991/93	1994 & Onward
Fuel, Operating & Maintenance cost	6.00	5.00	4.00
Buy-back rate	7.06	6.05	5.04

Exchange rate : 1 USD = 26 Baht

The buy-back rate of 1.10 Baht/kWh is approximated from the expected energy price and capacity price.

Financial Analysis

1. Simple payback period

$$\sum_{t=1}^{p} [R(t) - FC(t) - OMC(t)] = TIC$$

where,

R(t)	=	electricity sale (Baht/y),
FC	=	fuel cost (Baht/y),
OMC	=	O&M cost (Baht/y),
TIC	=	total installed cost (Baht)
P	=	simple payback period (y)

2. Internal rate of return (IRR)

IRR : i such that NPV (i) = 0

$$\sum_{t=1}^{n} \frac{[R(t) - FC(t) - OMC(t)]}{(1+i)^t} + \frac{SV(n)}{(1+i)^n} = TIC$$

where,

i = IRR (decimal),
SV = salvage value (Baht/y)

3. Levelized annual cost (LAC)

LAC = AC/AEO

where,

AC = annualized total cost (Baht/y)
AEO = annual electricity output (kWh/y)

4. Return on equity (ROE)

$$\sum_{t=1}^{n} \frac{[RD(t)-FC(t)-OMC(t)-IR(t)-T(t)]}{(1+i)^t} + \frac{SV(n)}{(1+i)^n} = E$$

where,

RD(t) = electricity sale-dept financing (Baht/y)
E = equity (Baht),
IR = interest on opening balance (Baht/y)
T(t) = tax (Baht/y)
i = Roe (decimal)

RESULTS AND DISCUSSIONS

Technical Feasibility:

(1) Boiler

Enthalpy of feed water	= 504 kJ/kg
Enthalpy of superheated steam	= 3,272 kJ/kg
Hourly production of steam	= $0.6 \times 237 \times 10^6 / (3,272-504)$
	= $\underline{51.4 \times 10^3}$ kg /hr

(2) Turbo-Generator

Enthalpy of exhaust steam	= 2,584 kJ/kg	
Turbo-generator output	= 0.85 (3,272-2,584)	
	= $\underline{584.8}$ kJ/kg	
	= $584.8 \times 51.4 \times 10^3$	= 30.0×10^6 kJ/hr
	= $\underline{8.33}$ MWe	

Total generating capacity from four plants = $\underline{33.3}$ MWe.

Financial Feasibility

Fuel Cost Baht/ton	Pay Back Period, years	IRR %	ROE	Electricity (1991) Cost, B/kWh
338	8.4	13.1	9.4	1.25
78	4.5	24.9	29.4	0.83
0	3.9	28.2	36.0	0.70

From the above result, the power generation from municipal wastes would not be financially feasible if the total cost of fuel is included in the evaluation. However, the cost of waste collection is currently paid by BMA and should not therefore be included in the fuel cost for the power plants.

In the near future, standards for emission at sources will be made compulsory. The cost of emission control for the boiler flue gas will probably increase the cost of electricity generation by about 10%.

Solid wastes such as metal, glass, etc. which are separated by the waste processing can be sold and therefore the cost of waste processing at about USD 3/ton can be partially recovered.

CONCLUSIONS AND RECOMMENDATIONS

The preliminary feasibility study of power generation from municipal wastes indicates that the cost of electricity should vary between 0.70 to 0.83 B/kWh if the cost of the waste collection is borne by the Bangkok Metropolitan Administration.

As an alternative scenario with the assumed buy-back rate of 1.10 Baht/kWh, the owner of the power plant would make enough profit to share a part of the waste collection cost with BMA.

A detail study based upon the optimum design of the power plant with emission control incorporated is recommended. With clear benefits from the feasible cost of electricity production and a hygienic method of waste disposal, a policy decision should be now made at national level to implement the power generation from municipal wastes.

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