Pre-Feasibility Study of Cogeneration in a Paper Recycling Mill in Bangladesh

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ABSTRACT

Pre-feasibility study of cogeneration in a paper recycling mill in Bangladesh was carried out. Information on steam and electricity consumption in the mill were collected through site visits and surveys via questionnaire. Historical energy consumption data show that the power to heat ratio of the plant was 0.35. To achieve an average power to heat ratio of 0.35, three types of the prime movers, i.e., steam turbine, reciprocating engine and gas turbine cogeneration system were considered. From the sensitivity analysis of the potential cogeneration alternatives of the mill, the reciprocating engine power match option, meeting the power requirement of 525 kW was found to be the most suitable cogeneration system. It represents an initial investment of 0.034 billion Taka (1 US $ = Tk 58) and leads to an internal rate of return of 41.8%.

Key words: Cogeneration, Energy consumption, Sensitivity analysis, Internal rate of return

INTRODUCTION

Pulp and paper mills are often large and complex facilities that may produce several pulp and paper qualities from both softwood and hardwood feedstock. However, it is possible to get an idea of relative energy performance across the industry by focussing on single-product facilities. Bleached and unbleached kraft pulping processes are essentially the same except bleached pulps are cooked to achieve a higher level of delignification in the digester, after which the pulp is bleached. As in most industries, new or modernized plants typically use less energy than old plants. Also, the industry has been more effective in reducing steam demand than electricity demand in new and retrofitted mills. State-of-the-art bleached kraft pulp mills use about 40% less steam and 5% less electricity then typical mills installed in the 1980s.

Bangladesh has acute shortage of primary energy resources which is hindering the growth of the energy sector. Energy conservation in particular and cogeneration is considered to be an attractive proposition in this context. Apart form the benefits in terms of incremental energy supply, cogeneration offers prospects for improving capacity utilization of industrial equipment and economic advantages. The major energy source of Bangladesh is natural gas. Its reserve is about 15 trillion cubic feet. In addition to this, a reserve of 2.5 trillion cubic feet of gas and oil in shallow waters of the Bay of Bengal is expected to be available for exploitation, (Centre for Energy Studies and Mechanical Engineering Department, 1998). The present gas production is about 715 million cubic feet per day. Coal deposits at shallow seams (135 m) at Barapukuria is also being developed with a targeted annual output of 8 million tons. The entire amount of petroleum products consumed in the country is imported in the forms of crude as well as refined products (Bangladesh National Conservation Strategy, 1996).

About 86 percent of the total electricity production depends on natural gas. Present peak demand of electricity is around 2,300 MW, while the generating capacity of grid is about 2,900 MW, (Bangladesh National Conservation Strategy, 1996). The actual capacity is however much lower due to older of the machines, problems of maintenance, availability of adequate fuel, frequent tripping of turbines and fluctuations in water at the sole hydroelectricity plant of the country. At present, only about 13 percent of the population has access to electricity. According to the National Energy Policy, the annual average growth in peak demand will be in access of 10% in order to help meet the demands in various end use sectors of economy. It is also estimated that capacity addition of 300-400 MW annually would be required even for meeting the needs of a modest growth. Today in the developed as well as the developing countries, conservation in general and cogeneration in particular are being given increasing attention to supplement the need for building new power plants. This issue needs due impetus in the context of the energy balancing of Bangladesh.

Cogeneration (combined heat and power or CHP) is set to play a major role in post-Kyoto carbon reduction strategies around the world, (Spinks, 1995). As well as cutting energy costs for a wide range of users, cogeneration uses fuel at very high efficiencies to reduce emissions of both carbon dioxide and other pollutants associated with combustion. Cogeneration is the simultaneous production of heat and electricity at, or close to, the point of use. It utilizes the heat that is inevitably produced in electricity generation from fuels to feed heating/cooling systems for buildings or directly in industrial process. By making use of this heat is the most efficient way of turning fuels into useful forms of energy. Cogeneration's high efficiency, typically 85% or more, compared to 35-50% for conventional power generation leads to its three main benefits: lower energy cost to users, reduced use of fuel and reduced emissions of polluting gases (Green, 1998). Since the power produced by an industrial cogeneration system becomes a by-product of the process, the incremental energy may be used as a source of captive supply or even wheeled-in to export energy to the grid (Mohanty and Oo, 1998).

ENERGY CLASS OF THE PLANT

The paper recycling mill requires both electrical and thermal energy. Electricity to the factory is supplied from the national grid and natural gas is used to generate steam in a low-pressure boiler which is mainly consumed for processing. Energy accounts for about 38% of the production cost of the industry (Green, 1998). Energy utilization in machinery's can be economized for better efficiency and for low production cost. The industry operates 24 hrs/day and about 340 days a year.

Current Energy Consumption

Electricity consumption

Analysis of the monthly electricity consumption by the 1997 is shown in Figure 1.

Maximum Electricity Consumption (Jan): 740 MWh
Minimum Electricity Consumption (Aug): 480 MWh
Maximum Electricity Demand: 1100 kW
Minimum Electricity Demand: 875 kW
Total Electricity Consumption in 1997: 7,433 MWh

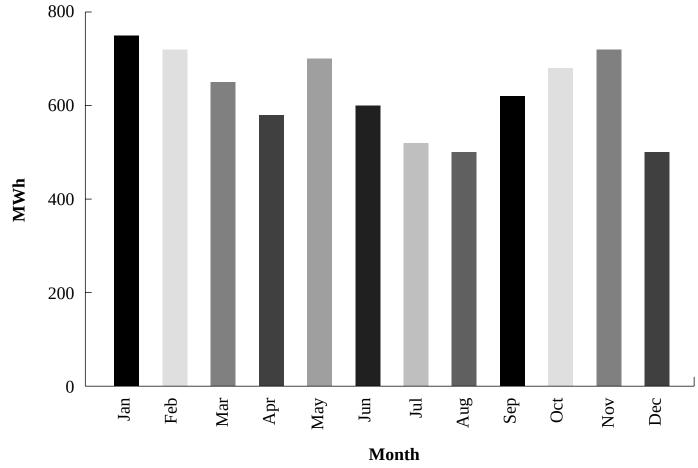

Figure 1. Monthly electricity consumption

Steam consumption

Analysis of the monthly steam consumption by the year 1997 is shown in Figure 2.

Maximum Steam Consumption (Jun): 3,872 Tons
Minimum Steam Consumption (Jun): 2,366 Tons
Total Steam Consumption in 1997: 38,201 Tons

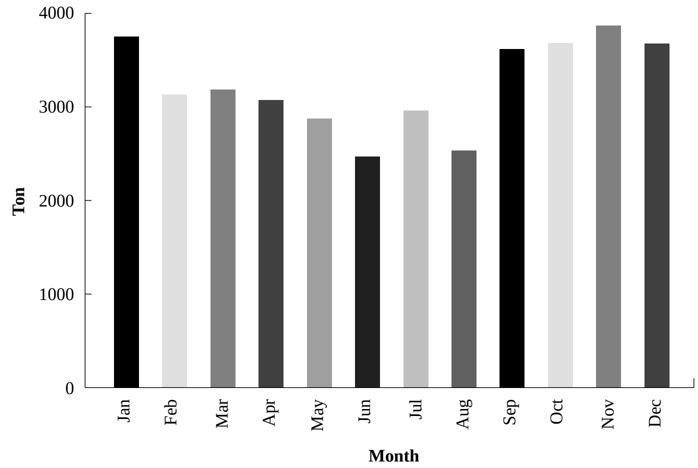

Figure 2. Monthly steam consumption

Power to Heat Ratio

Analysis of the power to heat ratio by the year 1997 is shown in Figure 3.

Maximum Power to Heat Ratio (Jun): 0.35
Minimum Power to Heat Ratio (Dec): 0.27
Average Power to Heat Ratio: 0.31

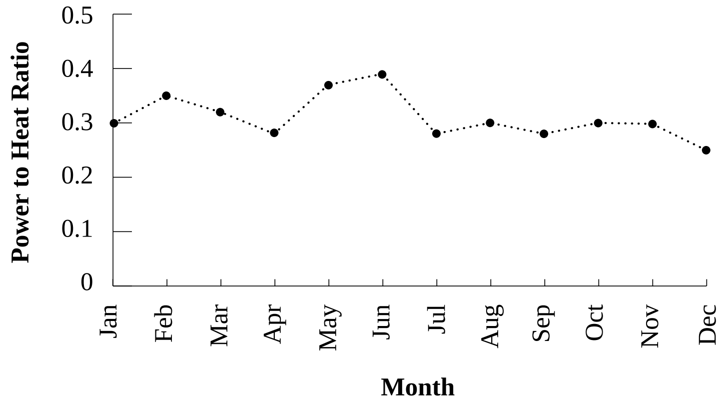

Figure 3. Power to heat ratio

ASSUMPTIONS USED IN PRE-FEASIBILITY STUDY

Assumptions used in pre-feasibility study in the spreadsheet analysis are given in Table 1.

Exchange Rate	Taka/US$	58
Tax Rate	%/Year	35
Service Life of the Cogeneration Plant	Year	15
Purchased Price of Electricity	Taka/kWh	3.6
Buy-back Rate	%	80
Fuel Price Escalation Rate	%	5-13
Electricity Price Escalation Rate	%	6-13
Stand by Rate	Taka/kW	80
Purchased Cost of Fuel (Natural Gas)	Taka/Cubic Meter	1.68

Table 1. Assumptions used in the pre-feasibility study.

Assumed installation cost of a CHP plant:

For a steam turbine: US$ 1200/kW
For a gas turbine: US$ 1000/kW
For a reciprocating engine: US$ 900/kW

The net present value (NPV) of cogeneration plant has been estimated as follow:

$$NPV = (CF)(AF)-(I)$$

$$AF = \frac{(1 + i)^n - 1}{i(1 + i)^n}$$

METHODOLOGY

Data on base electricity demand, steam demand, annual electricity consumption, annual thermal energy requirement were the initial inputs to the spreadsheet analysis. The spreadsheet of its own estimates the related parameters required for cogeneration analysis.

The steam turbine, reciprocating engine and gas turbine options with thermal match and power match results are shown in a computer print out of the spreadsheet analysis in Table 2. The results also show the internal rate of return on net investment for each option. Lastly, three alternatives were considered for sensitivity analysis.

COMMON DATA

Power to Heat Ratio (Required):	0.35
Actual Operating Hours:	8,160 hrs
Peak Electricity Demand:	1,100 kW
Peak Steam Demand:	5,663 kg/hr
Base Electricity Demand:	875 kW
Base Steam Demand:	3,400 kg/hr
Site Electricity Requirement:	7,433 MWh
Thermal Energy Requirement:	89.3 TJ
Fuel :	Natural gas
Calorific Value of fuel:	38 MJ/m^3

SUMMARY OF RESULTS

The results obtained from the spread sheet have been presented in Table 2.

Major Para-meters	ST		RE		GT	
	TM	PM	TM	PM	TM	PM
IP (kW)	238	875	4157	875	1,873	875
FC (TJ/Yr)	88.9	326.1	382.5	88.5	205.7	97.7
EG (MWh)	1,849	6,783	32,226	6,783	14,284	6,783
HG (TJ/yr)	73	267.8	73	15.4	73	34.7
E/D(-) P (MWh/yr)	-5,548	-650	24,793	-650	6,851	-650
E/DH (TJ/yr)	-16.3	151.8	-16.3	-73.9	-16.3	-54.6
EPHR	0.09	0.09	1.87	1.87	0.8	0.8
TI (million Taka)	13.7	50.4	179.59	37.8	88.4	42
NPV (million Taka)	16.9	20.3	234.1	68.4	110.8	64.5
IRR (%)	33.2	21.3	34.1	40.8	33.4	37.2

Table 2. Steam turbine, reciprocating engine and gas turbine option with thermal match and power match.

DISCUSSIONS

The steam turbine option does not seem promising: (i) with steam turbine thermal match (STTM), less than 21% of the power requirement is generated (ii) with steam turbine power match (STPM), 89% excess power and 172% excess heat is generated. This should not be considered for sensitivity study.

With the reciprocating engine thermal match (RETM) option, 320% excess power is generated. The project profitability will depend on the buy-back rate. This may not be a good option as the main purpose is not to earn from electricity sale. Reciprocating engine power match (REPM option seems as almost all power need can be met though heat generated is less than 78% of the requirement. There is a need to have auxiliary boiler.

With gas turbine thermal match (GTTM) option, about 87% excess electricity is generated which may not be acceptable. Gas turbine power match (GTPM) option is also good as heat deficit is around 62% which can be met by auxiliary natural gas firing in the recovery boiler and the total installation cost of GTPM is 51% less than GTTM.

Therefore, sensitivity analysis may be limited to REPM and GTPM options.

SENSITIVITY ANALYSIS

The sensitivity analysis carried out to see the impacts of the increase in the investment, fuel and electricity price escalation was limited to REPM and GTPM options. The sensitivity analysis of the factory is shown is Figure. 4, 5 and 6.

Figure. 4 shows that internal rate of return linearly decreases with increases of the investment cost for for REPM and GTPM options. As the investment cost increases from 1% to 15%, IRR varies from 41.5% to 36.5% for REPM and 36.8% to 33.8% for GTPM.

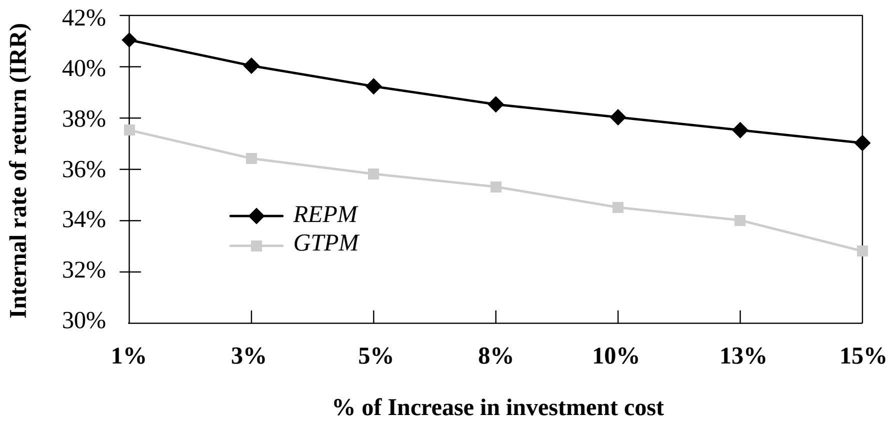

Figure 4. Internal rate of return versus investment cost

Figure. 5 shows that internal rate of return linearly decreases with increases of the fuel price escalation rate for REPM and GTPM options. As the fuel price escalation rate increases from 5% to 13%, IRR varies from 41% to 39.5% for REPM and 37.2% to 36.1% for GTPM.

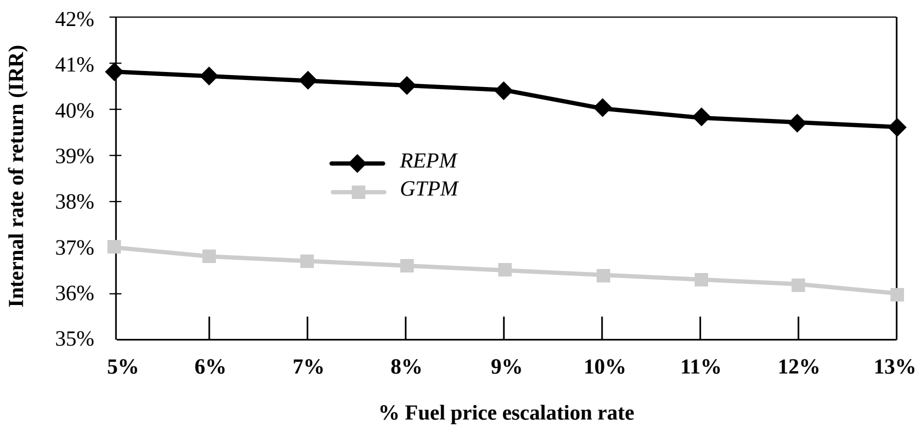

Figure 5. Internal rate of return versus fuel price escalation rate

Figure 6 shows that internal rate of return linearly increases with increases of the electricity price escalation rate for REPM and GTPM options. As the electricity price escalation rate increases from 6% to 13%, IRR varies from 41% to 47.5% for REPM and 37.2% to 43.1% for GTPM.

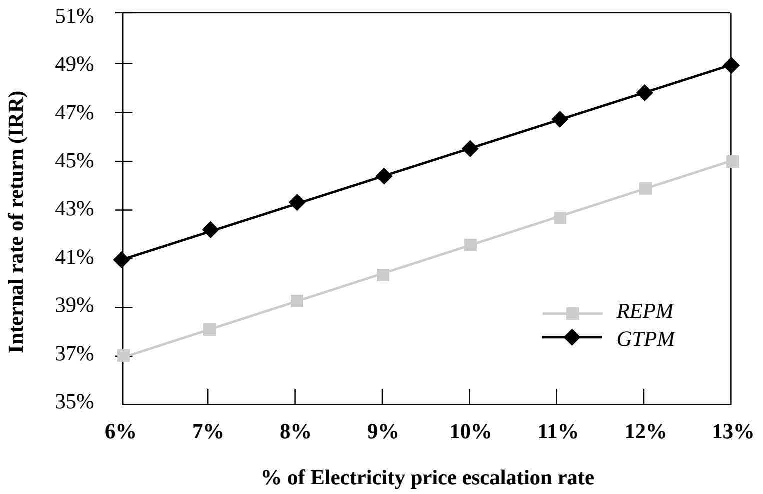

Figure 6. Internal rate of return versus electricity price escalation rate

CONCLUSION

From the sensitivity analysis of the potential cogeneration alternatives of the paper recycling mill, the reciprocating engine power match option, meeting power requirement of 875 kW would be the most suitable cogeneration system. It represents an initial investment of 37.8 million Taka and leads to an internal rate of return of 41.8%.

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NOMENCLATURE

CF = Cash flow for specific year	AF = Annuity factor	i = Discount rate
n = Predicted economic life of the plant	I = Investment	IP = Installed power (kW)
FC = Fuel consumption (TJ/Yr)	EG = Electricity Generated (MWh)	HG = Heat generated (TJ/yr)
E/DP = Excess/deficit(-) power (MWh/yr)	EPHR = Equipment power to heat ratio	
TI = Total investment (million Taka)	NPV = Net present value (million Taka)	
ST = Steam Turbine	GE = Gas Engine	GT = Gas Turbine
TM = Thermal Match	PM = Power Match	