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POTENTIAL FOR COGENERATION IN THE HOSPITAL SECTOR

C. CHULLABODHI, A. TERDYOTHIN & S. THUMVIVATNUKUN

School of Energy and Materials
King Mongkut's Institute of Technology Thonburi
Sukswas 48, Bangkok 10140

ABSTRACT

Information on heat and electrical consumptions in 30 government and private hospitals of different size, were collected through a survey. With the heat to power ratios of these hospitals being found to be in the range of 0.17 to 3.02, diesel cycle cogeneration system was considered to be the type suitable for potential evaluation. The analysis employed 2 different diesel cycle cogeneration systems of consecutive size range; the first being diesel fuelled units of 90 to 400 kW_e capacity, and the second, HFO fuelled engines, ranging from 800 kWe to 6 MWe. The results showed that only the largest hospital, Siriraj, passed the set financial criteria. of 25% IRR, or about 5 years payback period. Upon omitting the discount rate, imported duty and VAT, in the calculations, the number of hospitals meeting the criteria, increased to 3, namely, Siriraj, Ramathipbodi and Bangkok Christian, all of which are large hospitals, with the following system sizes and payback periods of 3.3 MW_e, 2.61 years; 1.8 MW_e, 3.87 years; and 1.3 MW_e, 4.78 years respectively. These findings seem to suggest that only 10 % of all hospitals have cogeneration potential. The reasons are obviously due to low operating hours, and energy consumption in general.

INTRODUCTION

Over the past 13 years, the electrical demand in the country has been increasing at a substantially high rate of about 11.86 % per annum [1], mainly due to expansion in economic activities, and rapid urbanization. The situation initiated the government to decide on integrated power planning, which included the demand strategies, as well as the supply considerations. Under this direction, emphasis was made on energy efficiency, and the participation of private sector in the supply side, which cogeneration appeared to satisfy both requirements.

The results of a potential study in the industrial sector [2], were used as guidelines in the formulation of the cogeneration supporting scheme by the government in 1992 [3], which dealt with the role of utilities in relation with the cogenerators. This information, however, did not give the whole picture of all the potential, as it did not cover other sectors, such as, commercial, in the study. Past works on energy analysis and conservation in this sector, for examples, [4,5,6], did not elaborate on this aspect either. Under these conditions, there appeared to be a need in the evaluation of cogeneration potential in the sectors other than industrial, the situation of which is quite different. The information gained would be of value to decision makers in further development of the cogeneration policy.

To be in line with the above concept, this cogeneration potential study has been undertaken, focussing on the hospitial sector, which is a subset of the commercial or building sector. The objective here is to evaluate the viability of using cogeneration system in the sample group of 30 hospitals.

METHODOLOGY

The data used for analysis were obtained through a survey. This was done after initial screening of the existing list of hospitals, both government and private, which numbered about 800 in 1992. For those having the number of beds below 100 and 30 for government, and private hospitals respectively, they were assumed of no potential, mainly due to low energy consumption. Of the remaining 181 hospitals, 30 were randomly selected for detailed potential evaluation. Their names, together with the number of beds, thermal and electrical loads, and the calculated values of heat-to-power ratio, for each hospital, appear as Annex A in the appendix.

As seen in the Annex, the heat-to-power ratio values of the selected hospitals are in the range of 0.17 to 3.02, with about two thirds of them having the values below 1.5. At these values, it is generally known that the cogeneration system of internal combustion engine type is the optimal plant, due to its better matching capability of the generated heat and electricity with the requirements. This system was hence chosen for detailed evaluation. In the process, information on energy flows through the system, and the cost would be required.

HFO fired systems were to be the principal type to be investigated, but due to the unavailability below 800 kWe size, diesel fuelled units from another firm had to be used also. The schematic diagram of the cogeneration system, together with the energy flow characteristics of each type may be seen in Fig. 1, and Table 1 respectively.

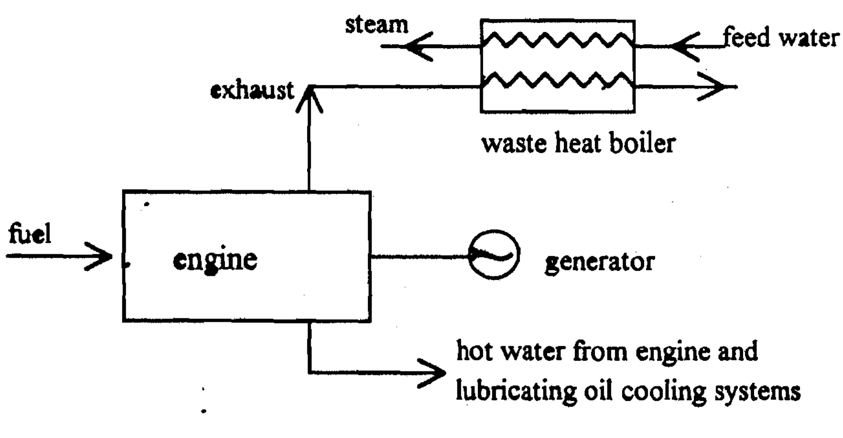

Fig. 1. Schematic of the System.

Table 1. Proportions of Energy Flow for the Two Systems Considered [7,8].

Energy	Diesel fuelled system	HFO fuelled system
from fuel	100	100
power generated	37.13	44.0
heat to cooling water	21.60	27.00
heat in flue gases	20.17	20.00
other losses	21.10	9.00

The total installed cost (TIC) which was developed from suppliers information [7,8] can be expressed by the equations:

$$TIC = 4.633 - 0.016\ P + 0.000021\ P^2 \quad \text{.......(1)}$$

$$TIC = 4.7234 - 1.4905\ PP + 0.2477\ (PP)^2 \quad \text{.......(2)}$$

where, equation (1) denotes total installed cost for diesel fuelled units, and in equation (2) for HFO - fuelled units.

P = power output in kWe
PP = power output in MWe

System Capacity

In determining the system capacity, thermal and electrical-matched approaches were used, with the evaluation method adapted from EPRI [9] as follows.

The gross heat rate (GHR) in either case, was estimated from equation (3) below, using the heat flow values shown in Table 1.

$$GHR = \frac{\text{system fuel consumption in kJ}}{\text{amount of electricity generated in kWh}} \quad \text{.......(3)}$$

Similarly, with information from the same source, the recoverable heat rate (RHR) could also be calculated from equation (4),

$$RHR = \frac{\text{amount of recoverable heat in kJ}}{\text{amount of electricity generated in kWh}} \quad \text{.......(4)}$$

Note that, in this study, the reclaimed heat from the engine and lubricating oil cooling systems was not considered, and the conversion efficiency of the waste heat boiler system was assumed to be 50 % [10].

For thermal-matched design, the capacity of the cogeneration unit could then be evaluated from,

$$P = \frac{m_S (h_S - h_W)}{RHR} \quad \text{.........(5)}$$

where, m_S = steam mass flowrate, kg/h
h_S, h_W = enthalpies of boiler steam and feed water, kJ/kg

In the case of electrical-matched approach, the size of the plant could be found from,

$$P = \frac{E}{8{,}760\ (CUF)} \quad \text{.........(6)}$$

where, E = annual electrical energy consumption, kWh/year
CUF = capacity utilization factor (assume 0.9 in this study)

Financial Evaluation

The criteria used for judging the viability of cogeneration in the studied hospitals, were the payback period (n), and the internal rate of return (IRR). For a hospital to have the potential, its n and IRR values should be less than 5 years, and more than 25 % respectively. The following equations were used in calculating the above values.

$$A = TIC \times CRF \quad \text{.........(7)}$$

where, A = annual net revenve, Baht/year
TIC = total installed cost of the system, Baht
CRF = capital recovery factor

$$= \frac{i(1+i)^n}{[(1+i)^n - 1]} \quad \text{.........(8)}$$

i = discount rate

And in the case of IRR,

$$\sum_{t=1}^{N} \frac{A}{(1+\frac{IRR}{100})^t} = TIC \quad \text{.........(9)}$$

where, t = number of years since project starts,
N = economic working life of the system

The evaluation of A is shown in Annex B.

RESULTS AND CONCLUSION

The results of the evaluation for each hospital as shown in Annex C, indicate that for the 30 hospitals investigated, only one hospital, Siriraj, is viable for cogeneration. The estimated system size is 3.3 MWe, with the payback period and IRR values of 3.6 years, and 33.3 % respectively. Most of the remainings show no saving at all. Electrical-matched approach appears to give a better return than the other in most cases, due to the fact that the majority of these hospitals require more heat than the cogeneration system can offer. This results in a smaller unit when using electrical matched criterion, which implies lower investment cost. The need for additional steam can also be economically met by operating the existing boiler. This arrangement yields better return than the thermal-matched case, where the investment cost is higher, and the amount of electricity shortfall has to be purchased at a relatively higher price.

In the situation where no taxes (imported duty 5 % + VAT 7 %) and discount rate, are included in the analysis , the results which are not shown in details here, indicate that there are 3 hospitals, namely, Siriraj, Ramathipbodi, and Bangkok Christian, passing the set financial criteria. The system sizes in these 3 cases, are 3.3, 1.8 and 1.3 MWe respectively.

To summarize the findings, the potential for cogeneration in the studied hospitals appears to be small (~ 6.4 MWe) with only 1-3 of the hospitals being viable, depending on whether the taxes and discount rate are included in the analysis or not. For the whole hospital sector, it is anticipated that the amount of potential would not be much different, as there is hardly any other hospitals of similar size as the ones that pass the set criteria.

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ANNEX A

ENERGY CONSUMPTION CHARACTERISTICS OF STUDIED HOSPITALS

Hospital Name	Monthly Consumption		Heat to Power Ratio
	Heat (GJ)	Electricity (MWh)	
Charoenkrung pracharagse	160.0	44.0	3.02
Prasrimahabodi	206.8	45.8	3.01
Betong	51.7	23.2	2.12
Krabi	82.7	40.2	2.11
Suanprung	51.7	24.4	2.01
Nan	251.3	69.7	2.00
Banmee	27.6	32.2	1.90
Sakolnakorn	172.3	76.6	1.87
Huachiao	1,545.1	473.8	1.81
Sraburi	413.5	171.8	1.78
Chaiyapum	119.2	65.9	1.50
Pattani	100.8	58.6	1.43
Nakornayok	102.0	93.5	1.21
Nongkai	102.0	80.4	1.05
Udonthani	206.8	168.3	1.02
Samutsongkram	68.0	65.1	0.94
Damnoensadouk	69.8	50.4	0.92
Ekachol	224.0	102.1	0.91
Nakornpanom	97.7	66.0	0.90
Srisangworn	60.3	62.6	0.81
Potharam	41.4	43.1	0.80
Siriraj	3,583.4	2,145.8	0.79
Phyathai 2	619.5	463.2	0.74
Ramathipbodi	1,688.6	1,194.4	0.67
Sukhumvit	136.0	233.9	0.55
Smitivej	689.2	558.0	0.54
Central	137.8	289.4	0.52
Srisakes	55.1	81.3	0.45
St. Louis	206.8	325.8	0.35
Bangkok Chirstian	310.9	826.3	0.17

ANNEX B

The annual net revenue (A), Baht/year, is the yearly income arising from the use of cogeneration system, minus the amount of expenses incurred during the same period.

The income terms consist of saving in purchased electricity, income obtained from selling excess electricity, and saving in fuel and maintenance costs of existing boiler.

The annual expenses include the fuel and maintenance costs of cogeneration system, depreciation cost, VAT associated with the sale of excess electricity, insurance premium, and standby charge.

In actual estimation, the following assumptions were used.

a). System life 15 years.
b). Electricity price included both demand and energy charges.
c). HFO and diesel prices, 2.77 and 8 Baht per litre respectively.
d). Buyback rate, 1 Baht/kWh.
e). Standby charge 54 Baht/kWe/month.
f). O & M cost for existing boiler, 5 % of fuel cost.
g). O & M cost for cogeneration system, per EPRI guidelines [9].
h). Depreciation rate, straight line with salvage value 1% of TIC.
i). VAT 7 %.
j). Insurance premium 0.5 % of TIC.

ANNEX C

DETAILED RESULTS OF FINANCIAL EVALUATION

Hospital Name	Design Mode	System Size (kWe)	Total Installed Cost (M Baht)	Payback Period (years)	IRR (%)
Charoenkrung pracharagse	TM	574	10.16	NS	NS
	EM	67	2.45	NS	NS
Prasrimahabodi	TM	596	10.31`	NS	NS
	EM	70	2.53	NS	NS
Betong	TM	213	4.64	NS	NS
	EM	36	1.47	NS	NS
Krabi	TM	366	5.82	NS	NS
	EM	62	2.31	NS	NS
Suanprung	TM	215	4.65	NS	NS
	EM	38	1.54	NS	NS
Nan	TM	602	10.35	NS	NS
	EM	107	3.38	NS	NS
Banmee	TM	264	4.94	NS	NS
	EM	49	1.91	NS	NS
Sakolnakorn	TM	620	10.48	NS	NS
	EM	117	3.57	NS	NS
Huachiao	TM	4,415	81.02	NS	NS
	EM	722	11.51	NS	NS
Sraburi	TM	1,576	46.30	NS	NS
	EM	262	4.93	NS	NS
Chaiyapum	TM	428	9.29	NS	NS
	EM	101	3.26	NS	NS
Pattani	TM	370	5.88	NS	NS
	EM	90	3.03	NS	NS
Nakornayok	TM	496	9.70	NS	NS
	EM	143	3.97	NS	NS
Nongkai	TM	372	5.90	NS	NS
	EM	123	3.67	NS	NS
Udonthani	TM	744	11.81	NS	NS
	EM	257	4.90	NS	NS
Samutsongkram	TM	248	4.85	NS	NS
	EM	100	3.24	NS	NS
Damnoensadouk	TM	201	4.55	NS	NS
	EM	77	2.71	NS	NS

Annex C continues

Hospital Name	Design Mode	System Size (kWe)	Total Installed Cost (M Baht)	Payback Period (years)	IRR (%)
Ekachol	TM	402	9.11	NS	NS
	EM	156	4.13	NS	NS
Nakornpanom	TM	237	4.79	NS	NS
	EM	101	3.26	NS	NS
Srisangworn	TM	217	4.67	NS	NS
	EM	96	3.16	NS	NS
Potharam	TM	149	4.05	NS	NS
	EM	66	2.42	NS	NS
Siriraj	TM	8,776	161.23	11.3	11.7
	EM	3,266	66.55	3.6	33.3
Phyathai 2	TM	1,484	64.15	NS	NS
	EM	705	26.72	NS	NS
Ramathipbodi	TM	4,134	76.99	11.2	11.8
	EM	1,818	50.05	5.9	21.5
Sukhumvit	TM	566	10.11	NS	NS
	EM	357	5.70	NS	NS
Smitivej	TM	1,576	46.30	NS	NS
	EM	850	30.83	19.21	7.21
Central	TM	660	10.82	NS	NS
	EM	442	9.38	NS	NS
Srisakes	TM	159	4.17	NS	NS
	EM	124	3.69	NS	NS
St. Louis	TM	496	9.70	NS	NS
	EM	496	9.70	NS	NS
Bangkok Chirstian	TM	638	10.63	NS	NS
	EM	1,258	40.43	7.79	16.55

Note : TM = thermal-matched design
EM = electrical-matched design
NS = no saving