CO-GENERATION TECHNOLOGY FOR HIGH EFFICIENCY CONVERSION OF NATURAL GAS ENERGY IN INDONESIA

by

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ABSTRACT

Very high efficiency energy conversion of natural gas can be obtained by simultaneous production of electricity and thermal energy. In industrial countries, this technology has been widely used in various industries, such as pulps, foods, oil refineries, and chemical industries. Moreover, it is becoming very popular and spans a wide spectrum of market, from the relatively small-scale residential and commercial consumers to large industrial plants.

In Indonesia, this technology has an open opportunity for application, particularly in support of the country's energy conservation and "blue sky" programmes. There are obvious reasons of using this technology, the reduction of fuel consumption of about 75%-80%, and the excess of electricity production can be sold to the public utility.

This paper will generally discuss the technology of gas co-generation, including its characteristics, and the economic and environmental considerations of using gas co-generation in Indonesia.

I. INTRODUCTION

In line with Indonesia's economic development, the country's energy consumption grows rapidly and its pattern moves from oil to natural gas. Natural gas is an alternative energy that has been developed in accordance with the diversification programme of the Government of Indonesia, which may promote energy utilisation effectively and efficiently.

The demand for natural gas in Indonesia is now concentrating in Java Island, about 0.9 BSCFD, and will increase to 3.3 BSCFD during the next decade. This may be because of the high growth of manufacturing and industrial sectors including electricity generation. Although the use of natural gas for electric generation has been started since the Third Five Year Development Plan (REPELITA III), it is still lower than for other uses. However, it has shown an increase of about 53 % over 5 years since 1986. Moreover, Indonesia's natural gas reserve amounts to about 123 TSCF where the big reserves are located offshore of Natuna Island and in East Kalimantan Province.

As demand for electricity has been also raising over the last decade, and its trend will be continued for the foreseeable future, PLN, as state own electricity company, is burdened with the responsible of providing the increasing supply of electric power for the public. Law No. 5/1989 on Electric Power has iterated the policy to include private sector's participation to generate and supply electric power for the public. For this matter, the Ministry of Mines and Energy has invited private sectors to build electric generation plants.

It is, therefore, crucial to identify the most promising technology for generating the electric power for certain area, such as the use of co-generation technology. This paper will also discuss the opportunities of using gas co-generation in Indonesia.

II. THE CHARACTERISTICS OF GAS CO-GENERATION

Gas co-generation is the simultaneous production of electrical or mechanical energy, plus heat, from a single fuel source such as natural gas. An engine will burn the fuel to produce power in form of electricity or mechanical drive, while thermal energy will be produced during this process and be covered for utilisation in various ways. Typical gas co-generation system is illustrated in Figure 1.

The characteristics of gas co-generation compared to other co-generation, steam co-generation (SC) and diesel co-generation (DC) are summarised in Table 1.

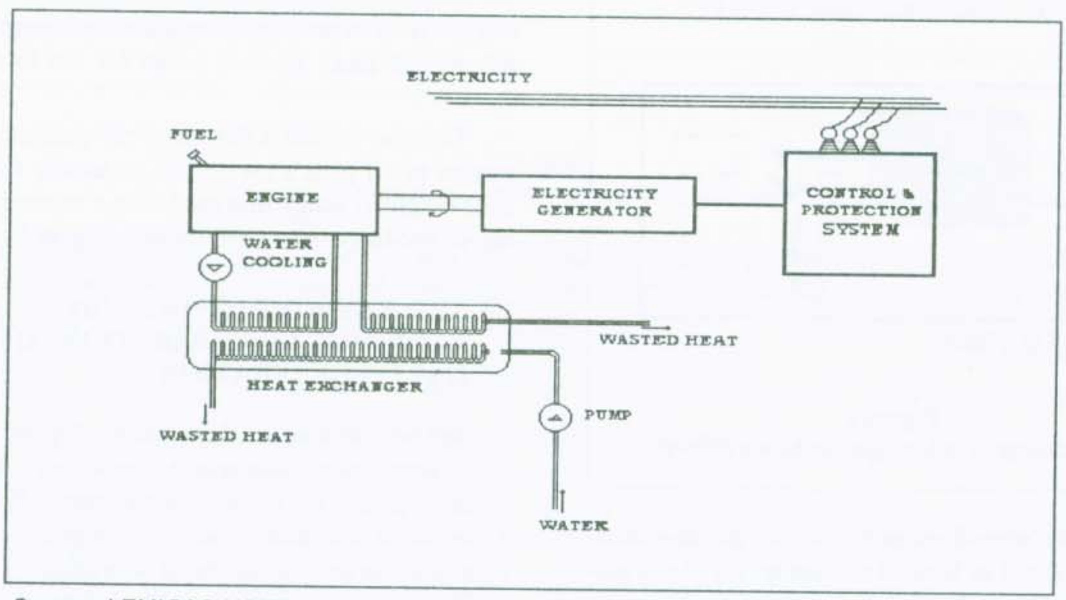
Natural gas, which is used as a fuel, is a mixture of hydrocarbons and a small amount of impurities such as moisture, carbon dioxide, nitrogen and hydrogen sulphide. It has different composition depending on its source. However, it dominantly consists of methane (about 85 to 90 %), as shown in Table 2.

The key factor of using gas co-generation is the reduction of fuel consumption as by utilising the otherwise unused heat, high overall efficiencies of about 75%-80% can be achieved, as shown in Figure 2.

Table 1
Characteristic of gas co-generation compared to diesel co-generation and steam co-generation

Characteristics	GC	DC	SC
Capacity (MW)	0.1-100	0.075-30	0.5-100
Electric power efficiency	24%-35%	25%-35%	14%-28%
The output ratio of Electricy and Thermal (kWh/M.cal)	0.56-09	0.6-0.9	0.12-0.45

Source : Rahman, F. (1991)



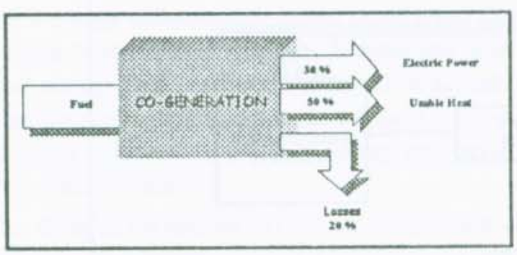
Source : LEMIGAS (1997)

Figure 1
Gas co-generation scheme

Table 2
The Composition of natural gas

Composition (% vol.)	Unit	Sources				
		South Sumatra	North Sumatra	Balikpapan	Cilamaya	Parigi
Methane	% vol.	78.9540	76.6048	90.1833	92.8744	97.2981
Ethane	% vol.	5.0244	10.5324	4.9721	3.1791	0.5699
Propane	% vol.	3.0721	6.3954	1.9452	0.5598	0.0200
Iso-Butane	% vol.	0.5946	1.7587	0.4664	0.0500	0.0000
n-Butane	% vol.	0.7333	1.8487	0.3871	0.0600	0.0000
Iso-Pentane	% vol.	0.2874	0.5996	0.1786	0.0200	0.0000
n-Pentane	% vol.	0.1982	0.3298	0.1092	0.0200	0.0000
Hexane plus	% vol.	0.6739	0.4397	0.1489	0.1999	0.0000
Water cont.	ppm vol.	8980	719	7556.8	273	224
H_2S	ppm vol.	4.4000	1.0000	0.0980	1.9000	0.8000
RSH	ppm vol.	3.1000	0.5000	0.0000	0.4000	0.0000

Source : PERTAMINA (1992)



Source : AGL (1996)

Figure 2
Efficiency of gas co-generation system

There are several characteristics of gas co-generation that enable it to be used efficiently: (1) Steam production that can be used for process heat, air conditioning, water desalination, space heating or industrial ovens; (2) Fluid heating that can be used for space heating systems, absorption air conditioning or meeting hot water requirements; (3) Direct heating, gas turbine exhaust is clean and unsaturated with water vapour. The hot product gases are well suited for use in ovens or dryer.

The other benefit is that electricity generated, that is surplus to the plant's own needs, is usually sold to the local electricity utility thus producing a revenue to offset capital and fuel costs, as illustrated in Figure 3.

III. THE ENVIRONMENTAL AND ECONOMIC CONSIDERATIONS OF USING GAS CO-GENERATION

In Order to support the "Blue Sky" programme of the Government of Indonesia, it is necessary that the use of gas co-generation would be environmentally friendly. Therefore, it is crucial to built gas co-generation in the right place in order to minimise its effects on the environment during construction and operation.

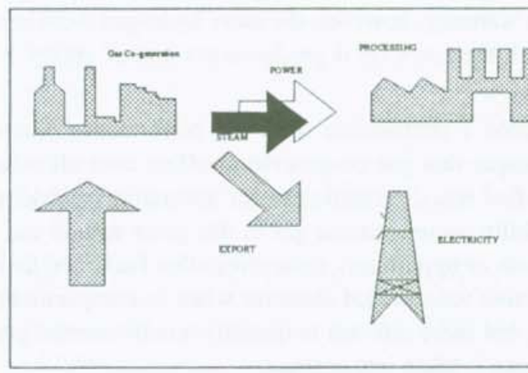
The location of gas co-generation depends upon its function, either main electric generation or emergency electric generation or combination of both of them. It also depends upon the distance from gas transmission line, when co-generation will use natural gas as a fuel.

Generally, as far as power generation is concerned, environmental considerations are focused mainly on :

- Acid rain, i.e. emissions of SO_X and NOx;
- The so-called greenhouse effect, i.e. emissions of CO_2, NO_X and water vapour;
- Air quality, i.e. emissions of SO_X, NOx and particulate;
- Disposal solid and liquid wastes;
- Decommissioning plants at the end of their useful life; and
- Safety at all stages from construction through to decommissioning.

NO_x will be involved in the acidification process in the natural environment. The effect of NO_x on the environment is associated with the production of ozone and acid rain which can damage building, increase fog formation, reduce visibility range and cause health problems, and also have a severe impacts on plants by developing acute leaf injury.

Sulphur is an impurity found in most forms of natural gas where during the combustion process, it reacts with oxygen to form, primarily, sulphur dioxide (SO_2). SO_2 is converted into sulphates and sulphuric acid in the atmosphere soon after emission that depends upon the



Source : Peebles, Malcom W.H. (1992)

Figure 3
The role of gas co-generation system

Table 3
Typical daily activity of gas co-generation

Plant type	Fuel consumed (tonnes)	Waste solids (tonnes)	Waste heat (GWh)	SO_2 produced (tonnes)	NO_x produced (tonnes)	CO_2 produced (tonnes)	Net efficiency (%)
NATURAL GAS							
– Conventional	7 800	Nil	70	Negligible	15–75	21 000	40
– Combined cycle	6 500	Nil	52	Negligible	10–50	18 000	48
FUEL OIL (3,5% sulphur)							
– Conventional	10 200	5*	73	750	40–70	33 000	39
COAL (1% sulphur)							
– Conventional	16 500	2 000*	76	350	50–150	39 000	38
– Combined cycle	14 800	1 800*	63	Negligible	10–50	35 000	43

* Plus sulphur

Source : Peebles, Malcom W.H. (1992)

degree of the sunlight, the moisture, hydrocarbons, and other reactive materials in the atmosphere. The SO_2 emissions may also result in the acidity of rainfall, and dark brown colour when it is absorbed by the plants, while the sulphuric acid leads to corrosion of metallic structures and building materials.

Carbon dioxide is the major emission that affects global warming, however, the more hydrogen there is in the fuel, the less CO_2 is produced per unit of energy released.

Table 3 summarises the main performance related advantages that gas co-generation offers over all other fossil fuel based technologies for generating electricity. The ability to use natural gas in this gives natural gas a premium or opportunity value over other fuels, and there are further value-added elements when its comparatively better, but more difficult to quantify, environmental performance is taken into account.

Where significant adverse effects are identified, a description of the mitigating actions should be taken to avoid, reduce or remedy those effects, e.g. to reduce NO_X emissions by using selective catalytic reduction. Particulate from co-generation that uses fuel oil can now be collected and removed down to acceptable levels by using Air Pollution Control Devices (APCD). However, both of these techniques are expensive.

From economic point of view, the capability of using thermal and electricity produced by the gas co-generation are the important factors to decide whether using gas co-generation is feasible or not. Therefore, it is necessary to analyse thermal and electric charges based on their consumption per hour.

The economic parameters, which are usually used in economic analysis of using gas co-generation, are described in Table 4.

It can be seen that gas co-generation (GC) is relatively lower in investment costs and operation costs than steam co-generation (SC) and diesel co-generation (DC). However, it is relatively higher in fuel costs than steam co-generation. It would economically have benefit when the location of gas co-generation is close to gas transmission line.

IV. OPPORTUNITIES FOR GAS CO-GENERATION IN INDONESIA

The strategy of gas co-generation operation in Indonesia is the most important factor that should be considered in order to develop the use of gas co-generation technology. Generally, there are three types of strategies of gas co-generation operation, the strategies of thermal necessity fulfilment, electricity necessity fulfilment, and maximum operation.

The strategy of thermal necessity fulfilment is the strategy where the production of gas co-generation will depend on the fluctuation of thermal necessity, without looking at the necessity of electricity. If the production of electricity is lower than its demand, the supply of electricity will come from outside, for example PLN; otherwise, the excess of electricity can be sold to the others.

Table 4
Economic characteristics for each type of co-generation

	GC	DC	SC
Investment Costs ($/kW)	500-600	400-800	550-1 600
Operation Costs ($/kW-year)	10-20	15-25	20-50
Fuel Costs (mills/kWh)	35-50	35-50	17-45

Source : Yudiartono (1993)

The second strategy, electricity necessity fulfilment, is usually used when the owner of gas co-generation has a problem, regarding its price, to sell the electricity to the public utility, and the all of electricity produced will be used for industrial process. In other word, no electricity will be sold to the public utility. If steam production is lower than its demand, the auxiliary boiler will do the supply of steam.

Maximum operation strategy is the strategy where gas co-generation will operate with maximum capacity without looking at thermal and electricity charges. If the production of electricity is higher than its demand, the excess of electricity can be sold to the public utility, while if there is thermal excess, it can be emitted directly or through condenser or radiator.

The natural gas utilisation programme will effectively and efficiently be implemented with the development of gas co-generation technology for industry, especially the industries which need high thermal for their process such as food industry, wood processing industry, chemical industry, pulp industry and oil refinery. In Indonesia these industries are large enough. Table 5 shows the projection of thermal needs for several industries.

In East Java, for example, there are many kinds of these industries that are potential for application of gas co-generation technology. If the efficiency of co-generation is 25 % and waste heat recovery efficiency is about 55 % with the gas co-generation system, while the boiler efficiency of the system without co-generation is 40 %, thus we can save the fuel is about 16,711 MMSCF per year or equivalent to 3 million BOE per year. These numbers, as indicated in Table 6, shows the promising opportunity of using gas co-generation technology in the provinces of Indonesia.

V. CONCLUSIONS

Based on the above discussion, the following points can be concluded:

- The use of gas co-generation is environmentally friendly, especially when it uses natural gas as a fuel. The emission resulted and the wastes solids or heats

Table 5
The projection of thermal needs for several industries in Indonesia
(Map-calorie, 10 calorie)

Type of Industries	1990	2000
Food	4.6	7.0
Sugar	12.7	18.8
Textile	2.6	3.8
Wood	3.7	5.5
Pulp (Paper)	3.2	5.8
Chemical	1.2	2.0
Total	28.0	42.9
Co-generation potential for new industries		1700 MW*

Source : Rahman, F. (1990)

* Assumption: capacity factor = 48 %; electricity efficiency = 25 %; system efficiency = 85 %, and CHP is operated with the strategy of thermal necessity fulfilment.

Table 6
The comparison of system with co-generation and without co-generation

	With co-generation MMSCF/year	Without co-generation MMSCF/year
Electricity production	8,931	8,931
Thermal production	32,749	32,748
Power generation eff	25 %	40 %
Waste recovery eff.	55 %	–
Fuels	46,551	63,262

Source : Ulap, Y. (1992)

produced from the Gas Co-generation are lower that they produced from Fuel Oil Co-generation.

- It will also have economically benefit as the investment and the operation costs are lower compared to Steam Co-generation and Diesel Co-generation.
- In order to support the government's programmes of energy diversification and blue sky environment, the use of co-generation with natural gas fuel in Indonesia will have a promising opportunity for implementation in the industrial area nearby the gas pipeline.

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