Potential of Natural Gas Based Cogeneration in Thailand

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Abstract: *Assessment of potential and resources for natural gas based cogeneration implementation in two energy sectors i.e. industry and commerce are reported in this paper. In addition - the possible and expected barriers for the implementation of cogeneration technology in the two above mentioned energy sectors in Thailand are also discussed. The total cost of investment and operation is estimated and proposed fiscal supporting measures and their effects have been analysed.*
Assuming that average efficiency of electricity generation is 39% for gas engines and 32% for gas turbines and these plants would operate 3,500 h/year in the case of designated buildings and 5,327 h/year in the case of designated factories. The result will be – around 3,300 MW_{el} power production with total primary fuel saving of 2,8 ktoe or 2.95% of total energy consumption in Thailand (2003).
Cogeneration can therefore make a significant contribution to the Thailand's sustainable energy goals and bring environmental, economic and social benefits. Cogeneration has the potential to make further significant contributions to security, diversity, competitiveness of energy supply and would help in supporting competitive manufacturing industries to use sustainable energy technologies in Thailand.

Keywords: Cogeneration, Natural Gas, Gas Turbines, Gas Engines, Energy Policy, Industry, Buildings, Thailand, Energy Efficiency

1. INTRODUCTION

The scope of this paper is to increase energy efficiency and improve security of energy supply by creating a framework for promotion and development of high efficiency cogeneration of heat and power (based on useful heat demand) and primary energy savings at the national energy market, taking into consideration the specific circumstances in Thailand - especially concerning climatic and economic conditions.

In the year 2003, the overall consumption of primary energy was 92,491 ktoe in Thailand. The aim of this paper is to provide ways for reducing this figure by implementing cogeneration technology. Assessments were performed until the year 2020. The growth of primary energy consumption in Thailand is expected to increase in compliance with the economic development and it is clear that with increased efficiency of energy transformations this growth can be mitigated. Thus volume of imported fuels and environmental externalities could be minimised especially global warming.

Possible and expected barriers for the implementation of cogeneration technology in the above mentioned two energy sectors in Thailand are discussed in detail. As the widespread use of cogeneration technology and distributed energy generation in other countries has also faced numerous non-technical barriers. This paper particularly deals with the analysis of these barriers and their mitigation measures [2]. The total cost of investment and operation is estimated and some fiscal supporting measures are proposed. Further the effect of these measures has been analysed.

For all the calculations in analysing possible potential of natural gas based cogeneration implementation, the DEDE (Department of Alternative Energy Development and Promotion) database was used [1]. Although this database has several deficiencies, currently it is the best database concerning energy consumption in Thailand. Base year for all the calculations throughout this paper is year 2003 [3]. The reason being - year 2003 is considered as economically stable and thus properly representing energy profile of all energy sectors in Thailand. On the other hand, statistical data is complete and easily accessible.

2. METHODOLOGY

2.1 Primary and final energy consumption in Thailand

The consumption of primary and final energy in Thailand is constantly growing. This particularly refers to the growth of the natural gas consumption which, in fact, enables the reduction of Heavy Fuel Oil (HFO) consumption in the industry. The Figure 1 shows primary and final energy consumption, as well as the primary energy consumption per sector. Taking into consideration the existing plans for the development of the natural gas distribution network in Thailand, it can be expected that by the year 2020 a significant part of industry and commercial buildings would be able to use natural gas. In compliance with such logic, the assessment of potential factories and commercial buildings (number and capacities) has been analysed. In Thailand, 1701 number of so called designated buildings and 2540 number of so called designated factories have been registered. It is estimated that other energy sectors are less attractive for utilising natural gas.

The main criterion for defining designated buildings is based on the total installed power and must be over 1,000 kW. The criterion for selection of designated factories could further sub-grouped into four categories based on installed electric power (IEP) a) IEP > 10000 kW b) 3000 < IEP < 10000 kW c) 2000 < IEP < 3000 kW and d) 1000 < IEP < 2000 kW.

The total electrical energy consumption of all designated buildings is app. 20% of total electricity consumption in commercial energy sector (Figure 1). Total final energy consumption of all designated factories is app. 70% of total final energy consumption in industry (Figure 1).

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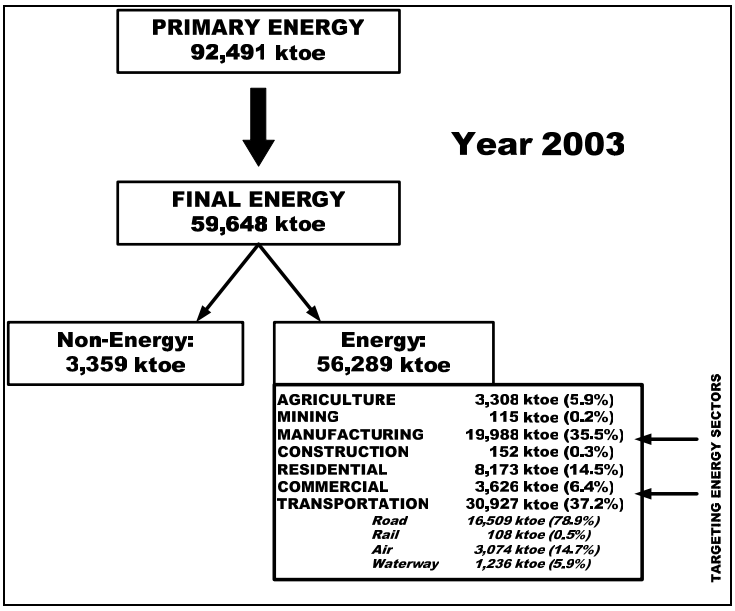

Fig. 1 Primary and Final Energy Consumption in Thailand (2003) [1]

2.2 Price of energy carriers

It is undeniably clear that price of energy carriers have a crucial impact on the economics of cogeneration projects. This is the reason why a detailed analysis of trend in price of energy carriers has been carried out in Thailand. The structure of energy carriers price has been exceptionally analyzed and possible trends of stimulation of potential users of cogeneration plants have been assessed. This analysis is not presented here due to the limited space; however the computation contains options with stimulating price of energy carriers.

The change of energy carriers price in Thailand during the period from January 2004 to May 2006 is shown in the Figure 2. It is especially important to point out that the ratio between the prices of electricity and of natural gas is falling, which has unfavourable effect on cogeneration projects. However, the ratio over 3 is still acceptable.

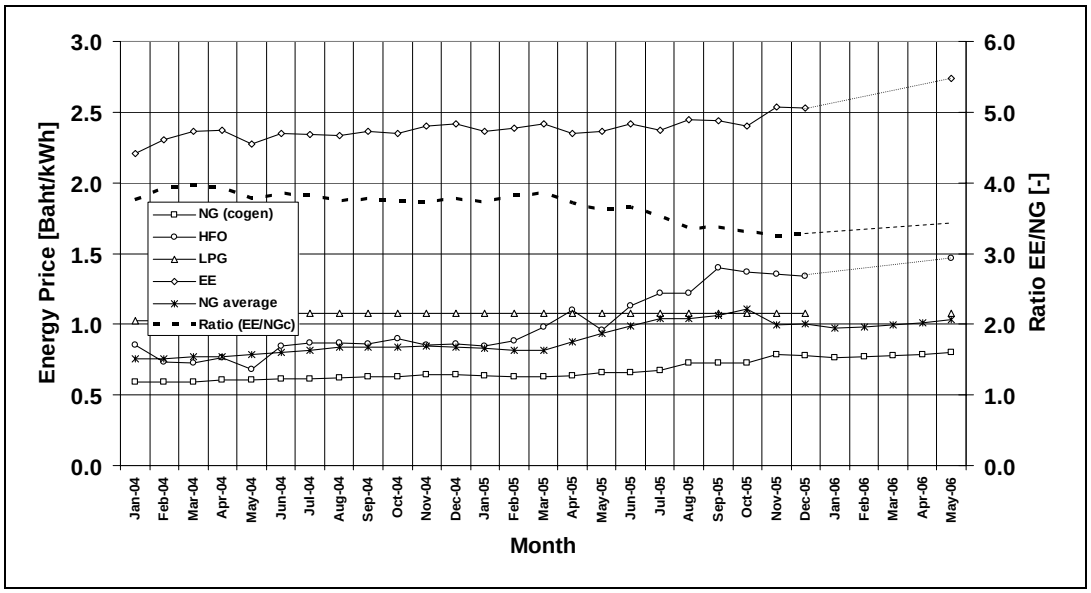

Fig. 2 Prices of Energy Carriers in Thailand

The price of energy carriers used for calculation in this paper is presented in the Table 1. These prices are calculated by using real price paid for energy and consumed energy in several factories and commercial buildings.

Table 1 Base energy prices in Thailand (2006) used in this paper

	Baht/kWh	1000 Baht/toe
Unit Price of NG for CHP	0.85	9.98
Unit Price of NG for industrial boilers	1.05	12.33
Unit Price of Electricity	2.80	32.88
Unit Price of LPG (with 30% subsidy: 3B/kg)	0.80	9.40
Unit Price of HFO	1.18	13.86
Average Price of Other Petroleum Products	1.20	14.09
Average Price of Coals	0.35	4.11
Average Price of Renewable Energy	0.25	2.94

2.3 Targeted designated buildings and industries

In detailed analysis on location of designated factories and buildings, it has been determined that there is a large concentration of these in only a dozen provinces in Thailand against a total of 75 numbers of provinces. In addition, the Development Plan for natural gas distribution network has mostly been connected with these provinces. In some cases, the number of operating hours of factories or the number of hours in which the systems in buildings have been engaged is very small and therefore these buildings are eliminated from further analysis. By eventual elimination of certain buildings and factories which are far from present and future network of natural gas pipelines, the final number of 966 designated buildings and 817 designated factories has been obtained.

Present consumption of electricity in selected designated buildings is 142.5 ktoe and in selected designated factories total final energy consumption is 7,435.0 ktoe.

2.4 Technology proposed

The specific features of this project concern to the use of natural gas for driving energy systems and an attempt to reduce energy consumption by replacement or partial replacement of existing energy systems and by increasing the energy efficiency. In the majority of observed buildings and factories, the required capacity of a newly created electrical or heat energy varies within the boundaries from 400 to 10 000 kW_{el} and related heat energy depending on applied cogeneration technology.

Out of numerous available options in cogeneration technology, only two options have been chosen i.e. gas engine and gas turbine. The Figure 3 shows the dependence of electrical power and efficiency of certain cogeneration technology options.

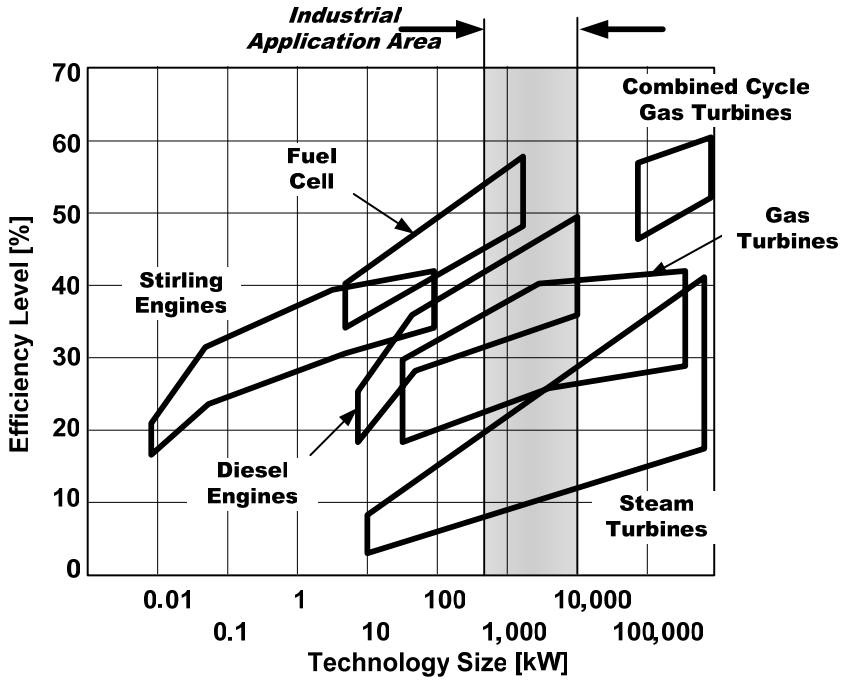

Fig. 3 Electrical Power Output versus Efficiency for Different Cogeneration Technologies

The Figure 4 shows simplified schematic of cogeneration technology applied in the case of designated buildings taking into considerations the climatic conditions of Thailand. The generated heat energy is used for driving absorption chillers. Only in rare situations, the heat is used for preparation of hot water.

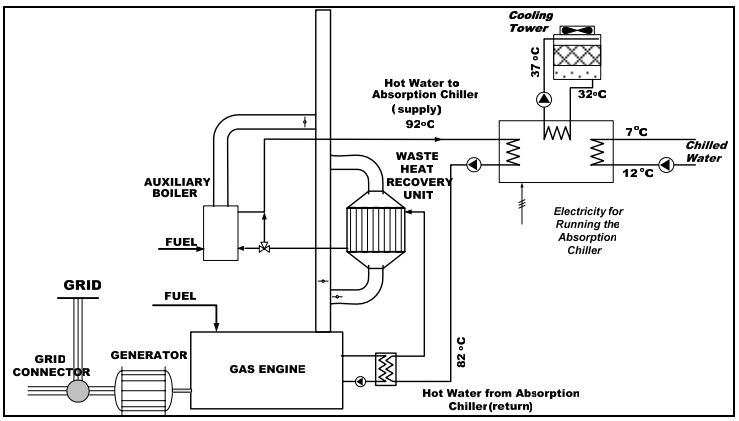

Fig. 4 Gas Engine and Absorption Chillers Scheme (for Commercial Buildings)

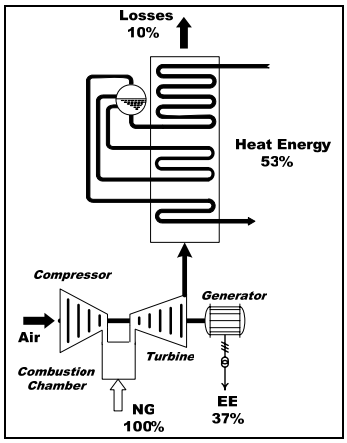

Fig. 5 Gas Turbine and Waste Heat Boiler Scheme (for Industry)

In the case of industry, the situation is completely different. The majority of industries require more heat energy than electricity. The typical schematic is presented in the Figure 5. The absorption chillers are not shown although it is technically feasible for use in the generation of chilled water. Figure 5 shows a gas turbine although in many factories a gas engine has been proposed.

3. RESULTS AND DISCUSSION

3.1 Summarized results of calculations

3.1.1 Designated buildings

The estimates presented in table 2 include 966 selected designated buildings. The base case assumes current price of electrical energy and natural gas. The Option 1 assumes providing stimulation of 30% for exported electrical energy to the national grid. The Option 2 assumes the price rise of electricity from 2.8 to 3.3 Baht and providing stimulation for exported electricity.

The adopted base energy price (1US$ ≈ 40 Baht) is average prices in the year 2006. It can be seen that the price of NG is lower than the average price of other fuels (primarily this is concerning HFO) which is applicable only to cogeneration plants in Thailand.

The estimate has been carried out with the basic assumption to meet cooling needs of designated buildings while electricity surplus will be exported to the local grid. From all the designated buildings suitable for implementation of cogeneration it is estimated that 85% of these will be in a position to build a plant by the year 2020.

The main purpose of stimulating measures in the form of increased electricity price for 30% (Option 1) and anticipated growth of this price and the use of stimulating measures for exporting electricity to the public grid (Option 2) is intended to provide conditions for reducing the simple pay back period, where as in the base case it is 10.7 years (Table 4).

Table 2 Energy consumption and cost for selected designated buildings

Energy Prices	Unit	Base Case	Option 1	Option 2
Unit Price of NG	Baht/kWh	0.85	0.85	0.85
Unit Price of Electricity	Baht/kWh	2.80	2.80	3.30
Ratio NG/EE Prices		3.29	3.29	3.88
Average Price of Other Fuels	Baht/kWh	1.20	1.20	1.20
Selected Buildings				
Current Electricity Consumption	ktoe/y	142.5	142.5	142.5
	GWh/y	1,673.1	1,673.1	1,673.1
Cost of Electricity	M Baht/y	4,685	4,685	5,521
Number of Operating Hours	h/y	3,500	3,500	3,500

The Table 3 contains part of calculations for required power of gas engines and corresponding absorption chiller output. In the Table 4, the cost and energy saving effects are presented.

Table 3 Gas engine and absorption chiller calculation

Gas Engines	Unit	Base Case	Option 1	Option 2
Refrigeration Power per Module	kW(Refrig)	427.1	427.1	427.1
Heat Power per Absorption Chiller Module	kW(Heat)	569.5	569.5	569.5
Heat to Power Ratio		1.10	1.10	1.10
Electricity Power per Module	kW(Elect.)	517.7	517.7	517.7
Total Efficiency of Cogeneration	%	80.00	80.00	80.00
Cost of Natural Gas	M Baht/y	3,907	3,907	3,907
Efficiency of Electricity Generation (NCV)	%	38.10	38.10	38.10
Total Electrical Power of Gas Engines	MWe	500	500	500
Total Electricity Production	GWh/y	1,751	1,751	1,751
Electricity can be sold to Public Grid	GWh/y	594	594	594

Gas Engines	Unit	Base Case	Option 1	Option 2
Stimulus for Exported Electricity	%	0.00	30.00	30.00
Price of Exported Electricity	Baht/kWh	2.80	3.64	4.29
Exported Electricity Revenue	M Baht/y	1,663	2,162	2,549
Cost of Energy	M Baht/y	2,244	1,745	1,359
Benefits of Cogeneration System	M Baht/y	2,441	2,940	4,162

Table 4 Investment cost and energy saving effect

Investment Costs	Unit	Base Case	Option 1	Option 2
Unit Cost of Module	US$/kW$_e$	**1,300**	**1,300**	**1,300**
All Module Price	M Baht	26,017	26,017	26,017
Simple Pay Back Period	Years	**10.7**	**8.9**	**6.3**
Energy Saving Effects				
Total Current Primary Energy (for electricity generation)	Ktoe	**372**	**372**	**372**
New Primary Energy Consumption	Ktoe	**391**	**391**	**391**
Primary Energy for Surplus of Electricity Generation	Ktoe	**132**	**132**	**132**
Primary Energy Saving	Ktoe	**113**	**113**	**113**
Percentage of Primary Energy Savings (Total)	%	**0.12%**	**0.12%**	**0.12%**
Percentage of Energy Savings (Commercial Sector)	%	**3.11%**	**3.11%**	**3.11%**

3.1.2 Designated factories

As far as designated factories are concerned, there are two additional criteria which were taken into consideration:

- Annual operating hours of a factory is over 4,500
- If demand electric power is less than 5 MW, then gas engine is considered. If demand electric power is over 5 MW, then gas turbine is considered.

The results are depicted in the Tables 5 and 6. Taking into consideration all designated factories from provinces where Natural Gas pipeline network can be expected by the year 2020, it is obtained that there are totally 817 factories which satisfy the criteria. In 118 of these factories, the average power is higher than 5 MW, which means that installing gas turbines will be a satisfactory technological solution. In the remaining 699, it would be much better to install gas engines. Their total electrical power is 2,771 MW. Average operating hours of facilities both in the case of gas engine and in the case of gas turbine exceed 7,000 hours per year. The consumption of HFO in factories is equal to 1,122 ktoe. HFO is primarily used for the steam production. The total cost of final energy for those factories is estimated to be 105 billion Baht/yr and only for fuels it is 48 billion Baht/yr.

Average electrical output of gas engine driven generator is 1.46 MW$_e$ and for gas turbine it is 9.87 MW$_e$ (for the climatic condition of Thailand). If these units are used as modules for the cogeneration capacity to be considered for the factories, it is obtained that on an average one gas engine or 1.5 gas turbines (in average) can meet the electricity demand of factories. Total electrical power will be 2,771 MW$_e$ if cogeneration is used in all 817 designated factories. It can be seen, that the simple pay back period will be around 3 years or even lower for the Option 1.

Table 5 Calculation of energy cost reduction for selected designated factories

	Unit	BASIC CASE			Option 1		
		Gas Engine	Gas Turbine	Both	Gas Engine	Gas Turbine	Both
Total Number of Modules for all Designated Factories	-	699	177		699	177	
Average Electricity Power per Designated Factory	MWe	1.46	14.81		1.46	14.81	
Electrical Output of Module (30 °C)	MWe	1.46	9.87		1.46	9.87	
Total Electrical Power Installed	MWe	1,024	1,747	2,771	1,024	1,747	2,771
Cogeneration Electricity Efficiency	%	39.0	31.5		39.0	31.5	
NG Consumption	GWh	19,483	40,563	60,046	19,483	40,563	60,046
Total Electricity Generated	GWh	7,598	12,777	20,376	7,598	12,777	20,376
Total Heat Energy Generated	GWh	8,378	20,485	28,862	8,378	20,485	28,862
Cost of Natural Gas	M Baht/y	16,561	34,479	51,039	16,561	34,479	51,039
Total Efficiency of Cogeneration	%	82.0	82.0		82.0	82.0	
Steam Production	ktoe	713.4	1,744.3	2,457.6	713.4	1,744.3	2,457.1
Price of Steam	M Baht/y	6,705	16,394	23,099	6,705	16,394	23,099
New Energy Cost	M Baht/y	38,675	37,585	76,260	38,675	37,585	76,260
Energy Cost Reduction	M Baht/y	11,420	17,692	29,112	15,219	24,081	39,300

Table 6 Investment costs for designated factories

	Unit	BASIC CASE			Option 1		
		GE	GT	Both	GE	GT	Both
Unit Cost of Module	US$/kWe	900	950		900	950	
All Module Price	M US$	921	1,660	2,582	921	1,660	2,582
	M Baht	36,858	66,404	103,262	36,858	66,404	103,262
Simple Pay Back Period	**years**	**3.2**	**3.8**		**2.4**	**2.8**	

3.2 Barriers

After the assessment of technical potentials and consideration of economic effects, it is necessary to develop instruments of energy policy and finally establish suitable environment to broaden the use of cogeneration technologies (Figure 6). Specified barriers have either been or still recognisable in other countries as well. It is still to be seen in which way the Government of Thailand is going to reduce them.

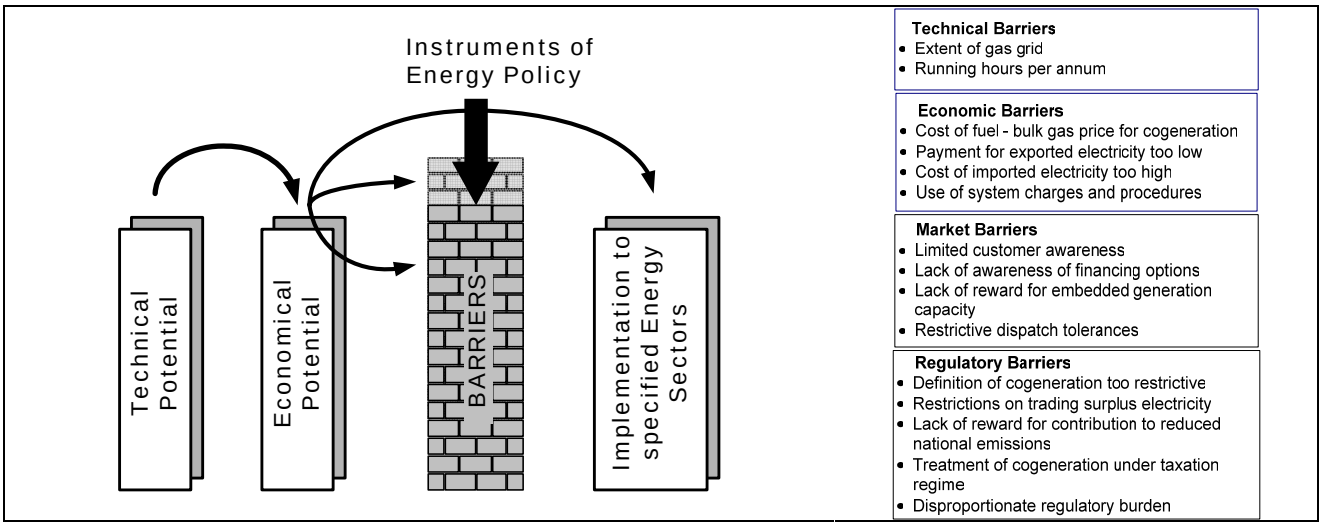

Fig. 6 Specification of barriers

3.3 Policy recommendations

- First there is a need to define, what is cogeneration that should be promoted based on its contribution to primary energy savings. The definition of cogeneration in electricity market could be adopted, like the one in the EU directive [4], which considers high efficiency CHP if a system saves more than 10% of the primary energy compared to other systems. Such a definition can be used to give high efficiency cogeneration system better promotion, better natural gas price and/or feed in tariff for excess tariff.
- Existing and future cogeneration projects should have its contribution to CO_2 reduction through:
  (a) Favourable treatment under Thailand's participation under Kyoto mechanisms.
  (b) Exemption from any carbon tax or similar levy.
- The new arrangements should incorporate minimum average price for surplus cogeneration sold to the grid and a maximum average price that cogeneration sites need to pay for electricity imported from the grid.
- Grid connection charges for cogeneration should be transparent, reflect only shallow connection costs, and shall exclude all deep reinforcement costs.
- Use of system charges should be based on average import/export volumes and not on maximum capacity.
- Cogeneration should receive financial credit for the contribution it makes to the grid as embedded generation.
- All cogeneration systems should be exempted from Public Service Obligation (PSO) levies.
- Government should prioritise the expansion of the natural gas pipeline network. This particularly refers to the distribution network which is still insufficiently developed.
- Probably the most favourable solution is to allow new private companies to takeover the responsibility of natural gas distribution and sale in Thailand, if the current institutions are not able to build up the distribution network.
- A fund may be established to finance all high-efficiency cogeneration systems in excess of 1 MWe.
- Cogeneration should be treated fairly as a flexible solution under all gas network procedures.
- Reduce regulatory burdens on cogeneration to proportionate level.

4. CONCLUSION

Assuming that average efficiency of electricity generation is 39% for gas engines and 32% for gas turbines and these plants would operate 3,500 h/year in the case of designated buildings and 5,327 h/year in the case of designated factories, the result will be around 3,271 MW_e power production with total primary fuel saving of 2,811 ktoe or 2.95% of total energy consumption in Thailand for the reference year 2003.

Power production of 3,271 MW_{el} is a real potential by having in mind experiences from other countries, especially the EU. The study concludes that the Government has to accomplish the target of achieving at least 2,000 MW of high-efficiency cogeneration capacities in industry and commercial buildings until 2020 and must develop a strategy to achieve it. Namely, many countries have based their plans only on technical and economical estimates disregarding slowness of the government system which should be included in the implementation of such an undertaking to a great extent.

5. ACKNOLEDGEMENT

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