COMBINED HEAT AND POWER:
COST EFFECTIVENESS, PROSPECTS AND TECHNOLOGY FOR MALAYSIAN PULP AND PAPER INDUSTRY

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ABSTRACT

Combined heat and power (CHP) systems (also known as CHP) generate electricity (and/or mechanical energy) and thermal energy in a single, integrated system. This contrasts with common practice in this country where electricity is generated at a central power plant, and on-site heating and cooling equipment is used to meet non-electric energy requirements. Because CHP captures the heat that would be otherwise be rejected in traditional separate generation of electric or mechanical energy, the total efficiency of these integrated systems is much greater than from separate systems. Recent technology developments have "enabled" new CHP system configurations that make a wider range of applications cost-effective. The significant increase in efficiency with CHP results in lower fuel consumption and reduced emissions compared with separate generation of heat and power. As part of its strategy for reducing greenhouse gas emissions, the Government is committed to encouraging the growth of CHP as part of the Energy Efficient Programs. This thesis is based on identifying the potential of CHP programs in Malaysian Industry, mainly in Pulp and Paper sub-sector and to rank the best CHP technologies available to be implemented and then to device strategies to attract industrial sector to consider CHP in their plants. A thorough understanding of the industrial process flow is necessary in order to plan a CHP model. Literature reviews, study of energy audit report by PTM and software based analysis were critical aspects of the methodology used in this project. The analysis on the cost effectiveness of CHP will be performed to three case studies using software called RETScreen. The priority of available CHP options were weighed according to the pay back period (PBP), internal rate of return (IRR), net present value (NPV) and also the greenhouse gas (GHG) emission reduction cost. As a conclusion, industries with similar facilities as the case studies can apply the CHP options to view the potential of CHP in Malaysian Industry. This thesis also forwarded recommendations and suggestions that will be required to improve the CHP scenario in Malaysia.

ABSTRAK

Gabungan haba dan kuasa ataupun dalam bahasa Inggerisnya ‘Combined heat and power (CHP)’ merupakan suatu sistem integrasi yang menjanakan kuasa elektrik dan juga kuasa terma di dalam satu masa. Ini sangatlah berbeza dengan praktis yang ada di Malaysia sekarang dimana kuasa elektrik dijanakan di pusat stesen janalektrik dan penjanaan kuasa terma dan sejuk yang selalunya untuk proses industri di buat di lokasi. Disebabkan CHP dapat menggunakan semula tenaga haba yang hilang oleh proses penjanaan kuasa yang lazim,maka tahap kecekapan sistem adalah lebih baik. Pembaharuan dari segi teknologi CHP sekarang membolehkan sistem ini dapat digunapakai secara meluas kepada semua sektor industri mahupun komersil. Sebab utama yang menyumbang kepada kecekapan yang tinggi kerana pengurangan di dalam penggunaan minyak dan juga pelepasan gas berbahaya atau ‘Greenhouse Gas (GHG)’. Berikutan daripada perjanjian Kyoto yang telah di tandatangani oleh kerajaan pada tahun 2002, maka fokus kerajaan adalah untuk mengurangkan pelepasan GHG ini. Bagi mencapai matlamat tersebut berbagai aktiviti seperti Kecekapan Tenaga (‘Energy Efficiency’) selain menyokong perkembangan CHP di Malaysia. Tesis ini bertujuan untuk mengenalpasti potensi CHP di dalam sektor industri terutamanya industri pulpa dan kertas (‘Pulp and Paper’) dan membuat perbandingan teknologi CHP yang paling sesuai buat industri ini. Pemahaman yang mendalam mengenai proses industri ini adalah perlu sebelum projek CHP dapat di kenalpasti melalui laporan audit tenaga oleh Pusat Tenaga Malaysia (PTM). Seterusnya analisa keberkesanan kos di buat dengan program bernama ‘RETScreen’. Antara aspek yang dikaji adalah tempoh pulangan modal (‘Payback period’), kadar pulangan dalaman (‘Internal rate of return’), nilai semasa (‘Net present value’) serta pengurangan kos pelepasan GHG. Seterusnya hasil daripada tesis ini boleh digunakan kepada industri lain yang mempunyai aplikasi tenaga haba yang sama. Selain itu tesis ini juga memberi cadangan serta pandangan untuk menaikkan tahap penggunaan CHP di Malaysia.

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Gabungan haba dan kuasa ataupun dalam bahasa Inggerisnya ‘Combined heat and power (CHP)’ merupakan suatu sistem integrasi yang menjanakan kuasa elektrik dan juga kuasa terma di dalam satu masa. Ini sangatlah berbeza dengan praktis yang ada di Malaysia sekarang dimana kuasa elektrik dijanakan di pusat stesen janalektrik dan penjanaan kuasa terma dan sejuk yang selalunya untuk proses industri di buat di lokasi. Disebabkan CHP dapat menggunakan semula tenaga haba yang hilang oleh proses penjanaan kuasa yang lazim,maka tahap kecekapan sistem adalah lebih baik. Pembaharuan dari segi teknologi CHP sekarang membolehkan sistem ini dapat digunapakai secara meluas kepada semua sektor industri mahupun komersil. Sebab utama yang menyumbang kepada kecekapan yang tinggi kerana pengurangan di dalam penggunaan minyak dan juga pelepasan gas berbahaya atau ‘Greenhouse Gas (GHG)’. Berikutan daripada perjanjian Kyoto yang telah di tandatangani oleh kerajaan pada tahun 2002, maka fokus kerajaan adalah untuk mengurangkan pelepasan GHG ini. Bagi mencapai matlamat tersebut berbagai aktiviti seperti Kecekapan Tenaga (‘Energy Efficiency’) selain menyokong perkembangan CHP di Malaysia. Tesis ini bertujuan untuk mengenalpasti potensi CHP di dalam sektor industri terutamanya industri pulpa dan kertas (‘Pulp and Paper’) dan membuat perbandingan teknologi CHP yang paling sesuai buat industri ini. Pemahaman yang mendalam mengenai proses industri ini adalah perlu sebelum projek CHP dapat di kenalpasti melalui laporan audit tenaga oleh Pusat Tenaga Malaysia (PTM). Seterusnya analisa keberkesanan kos di buat dengan program bernama ‘RETScreen’. Antara aspek yang dikaji adalah tempoh pulangan modal (‘Payback period’), kadar pulangan dalaman (‘Internal rate of return’), nilai semasa (‘Net present value’) serta pengurangan kos pelepasan GHG. Seterusnya hasil daripada tesis ini boleh digunakan kepada industri lain yang mempunyai aplikasi tenaga haba yang sama. Selain itu tesis ini juga memberi cadangan serta pandangan untuk menaikkan tahap penggunaan CHP di Malaysia.

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LIST OF SYMBOLS/ABBREVIATIONS

CHP	-	Combined Heat and Power
CO	-	Carbon Monoxide
CO2	-	Carbon Dioxide
GDP	-	Growth Domestic Product
GHG	-	Greenhouse Gas
IPP	-	Independent Power Producer
IRR	-	Internal Rate of Return
KW	-	Kilowatt
KWh	-	Kilowatt hour
MW	-	Megawatt
MWh	-	Megawatt hour
NOx	-	Nitrogen Monoxide
NPV	-	Net Present Value
O&M	-	Operation and Maintenance
PEFC	-	Proton Emission Fuel Cell
PTM	-	Pusat Tenaga Malaysia
RET	-	Renewable Energy Technology
SO2	-	Sulfur Dioxide
SP	-	Simple Payback
ST	-	Suruhanjaya Tenaga
TNB	-	Tenaga Nasional Berhad

CHAPTER 1

STATUS OF COMBINED HEAT AND POWER IN INDUSTRIAL SECTOR IN MALAYSIA

1.1 Introduction

The manufacturing sector in Malaysia is a major consumer of energy in its primary form as various fuels and in its secondary form as electricity. Some industries are electricity intensive, e.g. electronics, textiles (spinning and weaving), steel fabrication. There are also industries that are heavily fuel intensive, such as glass manufacturing, steel making, ceramics manufacturing. The last category of industry is that which consumes both fuel and electricity in significant proportions. For the latter two categories of industries, there is promise for the introduction of Combined Heat and Power (CHP) plants into these industries for self consumption and export of electricity to the National Grid.

This study is carried out to ascertain the economic and financial viability of introducing CHP into the manufacturing sector mainly the Pulp and Paper Industry. As Natural Gas is an indigenous product of the petroleum industry in Malaysia, and it is the intention to encourage the widespread use of Natural Gas in Malaysia for various reasons, this study is focused on CHP plants fired on Natural Gas only.

1.2 Malaysian Energy Trends, 1990- 2003

Table 1.1 below gives selected energy and economic data from 1990 to 2003. The trends in Growth Domestic Product (GDP), primary energy supply and final energy demand for the duration are given in Figure 1.1. There has been significant growth in the energy scene in the past years, primary supply which was recorded at 50452 ktoe in 2001, increased to 50749 ktoe and increased further to 54,194 ktoe in 2003. GDP grew from RM 219309 million in 2002 to RM 231674 million in 2003, i.e. by 5.5% as compared to 4.1% in 2002.

Table 1.1 : GDP, Population, Primary Energy Supply, Energy Demand and Electricity Demand (1990 – 2003)

Year	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
GDP at 1987 prices (RM million)	111061	166625	183292	197120	182331	192795	209365	210188	219309	231674
Population ('000 people)	18102	20624	21101	21595	22107	22636	23418	23935	24447	24967
Primary Energy Supply (ktoe)	19661	30893	35612	36550	36288	37245	47887	50452	50749	54195
Final Energy Demand (ktoe)	13217	22164	24167	26168	25558	27228	29699	31515	33290	34585
Electricity Demand (ktoe)	1715	3375	3777	4384	4577	4815	5263	5594	5922	6313
Electricity Demand (GWh)	19932	39225	43897	50955	53187	55912	60299	63043	66991	71159

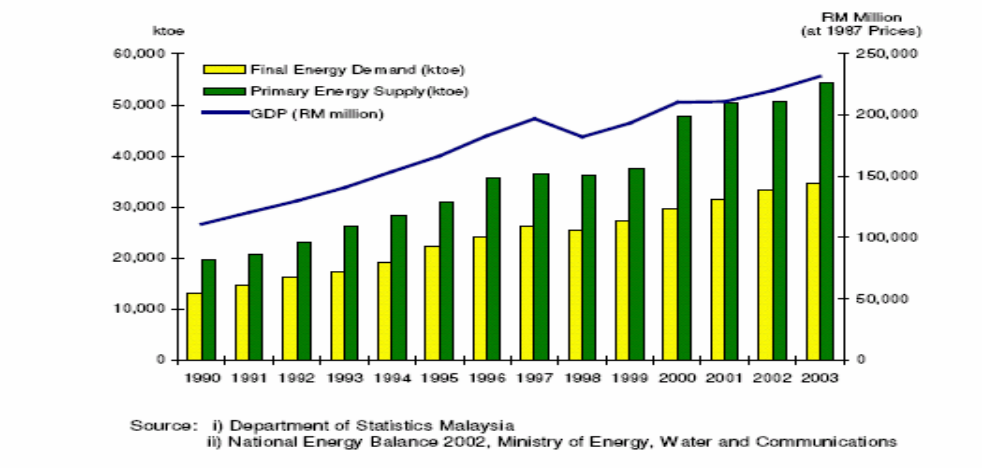
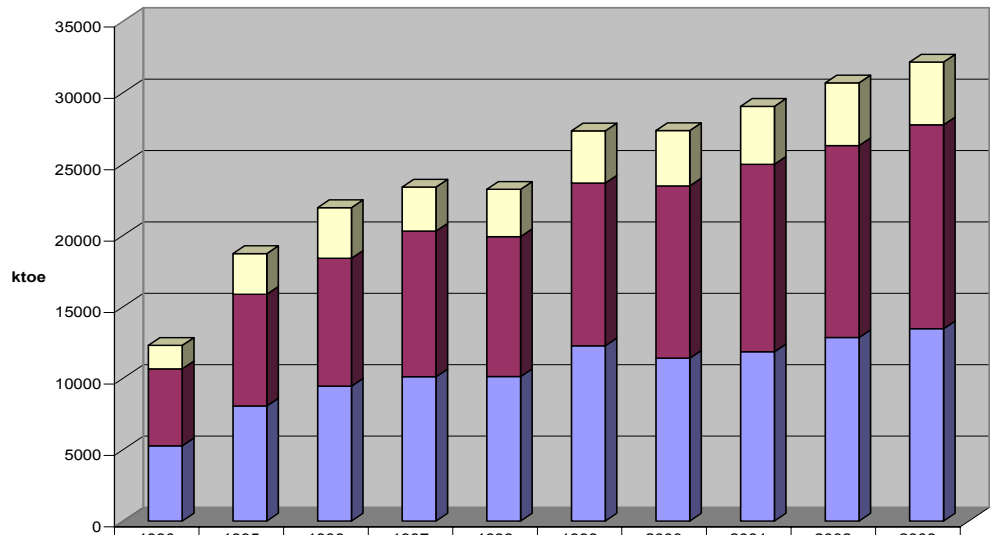


Figure 1.1 : Trends in GDP, Primary Energy Supply and Final Energy Demand

1.3 Malaysian Final Energy Demand, 1990 - 2003

Figure 1.2 below depicts the final demand by sectors from 1990 to 2003. It can be seen that Malaysia's energy demand was dominated by two largest consumers i.e. the transportation and industrial sectors. These two sectors together consumed almost 80% of total final energy demand in the country for more than two decades. Over the period 1990—2003, energy demand of the industrial sector grew at an average of 6.9% per annum due to the rapid industrialization process taken place in the country. At the same time, energy consumption in the transport sector grew at 8.4% per annum, mainly due to the increase in population as well as income per capita.

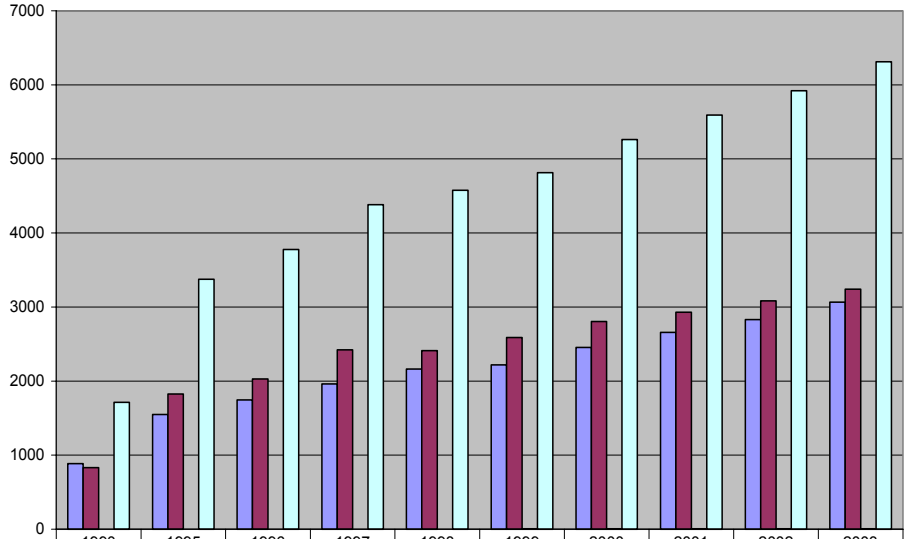


	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Residential and Commercial	1646	2837	3557	3073	3314	3653	3868	4048	4387	4399
Transport	5387	7827	8951	10201	9793	11393	12071	13137	13442	14271
Industrial	5276	8060	9443	10106	10121	12277	11406	11852	12854	13472

Figure 1.2 : Final Energy Demand by Sector (1990 – 2003)

1.4 Malaysian Electricity Demand and Supply, 1990 - 2003

Electrical consumption by sectors from 1990 to 2003 is given in Figure 1.3 below.



	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Resid. & Comm.	885	1549	1747	1961	2165	2220	2453	2660	2831	3066
Industrial	830	1826	2029	2422	2411	2591	2805	2930	3086	3242
Transport	0	0	1	1	1	4	4	4	5	5
Total Electricity Demand	1715	3375	3777	4384	4577	4815	5262	5594	5922	6313

Figure 1.3 : Electricity Consumption by Sectors (1990 – 2003) in ktoe

Industrial sector has always been the biggest user of electricity. In 2003 the sector consumed about 51% of electricity generated. Residential and commercial consumed 48% (19% Residential and 29% Commercial), while public lighting, mining and other sectors consumed about 1%. Peak demand in Peninsular Malaysia alone has grown from 3447 Megawatts in 1990 to 9712 Megawatts in 2000 and 11,329 Megawatts in 2003. In 2003, 72.5% of the 83,300 GWh electricity generated used gas, 16.5% coal, and 6.2% from Hydro power. Only about 0.5% of the electricity was generated from biomass.

1.5 Market Growth Forecast

According to the Third Outline Perspective Plan (OPP3), the Malaysian economy is expected to grow by 7.5% in the decade of 2001-2010. The actual GDP recorded for the year 2003 was 4.2%. It is estimated that the total final energy demand will grow between 5% to 7.9% per annum for the next 20 years compared with a growth rate of 3.6% to 10% in 1980-98 period. It is expected that beyond 2005, the annual growth rate of final energy demand will be, to a certain extent, lower than the GDP growth. This indicates that the energy intensity is expected to decline slightly due to technological developments and the increasing use of more energy efficient equipment and processes.

In order to meet the electricity demand in the future, a total of 9,570 MW of new generation capacity will be planted between 2002 and 2007 in the Peninsula Malaysia. As a step to improve Malaysia's fuel diversity 5,600 MW will be coal fired power plant. By the year 2007, the fuel mix for electricity generation in Peninsular Malaysia will be 50-55% on natural gas, 30-35% on coal and the remaining on hydro, oil and renewable energy. In Sabah and Sarawak, the 2,400 MW capacity of hydro project is under construction now and is expected to be able to meet the future demand in Sabah and Sarawak.

The growth of final energy demand especially in industrial sector has become the government's concern lately. This is mainly due to the increase in oil prices in the world and Malaysia will not have enough oil reserve if the growth continues with no measures taken on the Energy Efficiency or Demand Side Management.

1.6 Overview of Combined Heat and Power (CHP)

Traditionally, electricity has been produced by power plants that burn fuel to drive electric generators. These power plants create a large amount of heat wasted in the process of producing electricity. This unused energy may equal up to 67% of the energy content of the fuel in a typical power plant. In the past, industries that needed large amounts of steam heat in their manufacturing processes such as pulp and paper mills, petroleum producers and food processors had two choices. They could make steam on-site burning fuel in a boiler and provide their electricity needs separately through the local utility. This has been called separate heat and power. Or they could generate electricity on-site and use the waste heat from that process to create steam. Providing both electric power and heat from a single source is called combined heat and power (CHP).

While separate heat and power systems are often only 33% efficient (67% of the fuel energy is wasted), CHP can be 60% to 90% efficient by capturing and making productive use of the waste heat on-site. There are many valuable uses for waste heat. Food processors need steam to can fruits and vegetables; commercial laundries use hot water for washing; health clubs heat water for swimming pools, showers, whirlpools and saunas. CHP can also serve facilities that need cooling or refrigeration by using the heat to drive modern heat absorption chiller and refrigeration technologies.

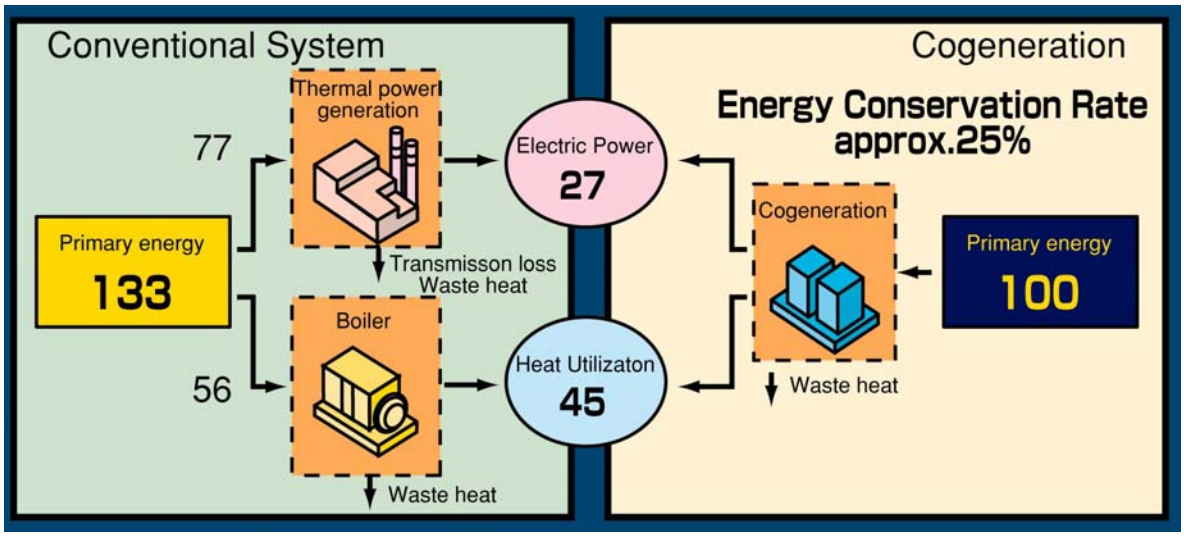


Figure 1.4 : Conventional System Compared to Cogeneration (CHP) System in terms of Energy Conservation Rate

Figure 1.4 above illustrated the energy conservation that can be saved if the same plant uses CHP system. With the same amount of electric power and heat utilization output, the primary energy (usually fuels) for CHP are 100 unit compared to separate heat and power system.

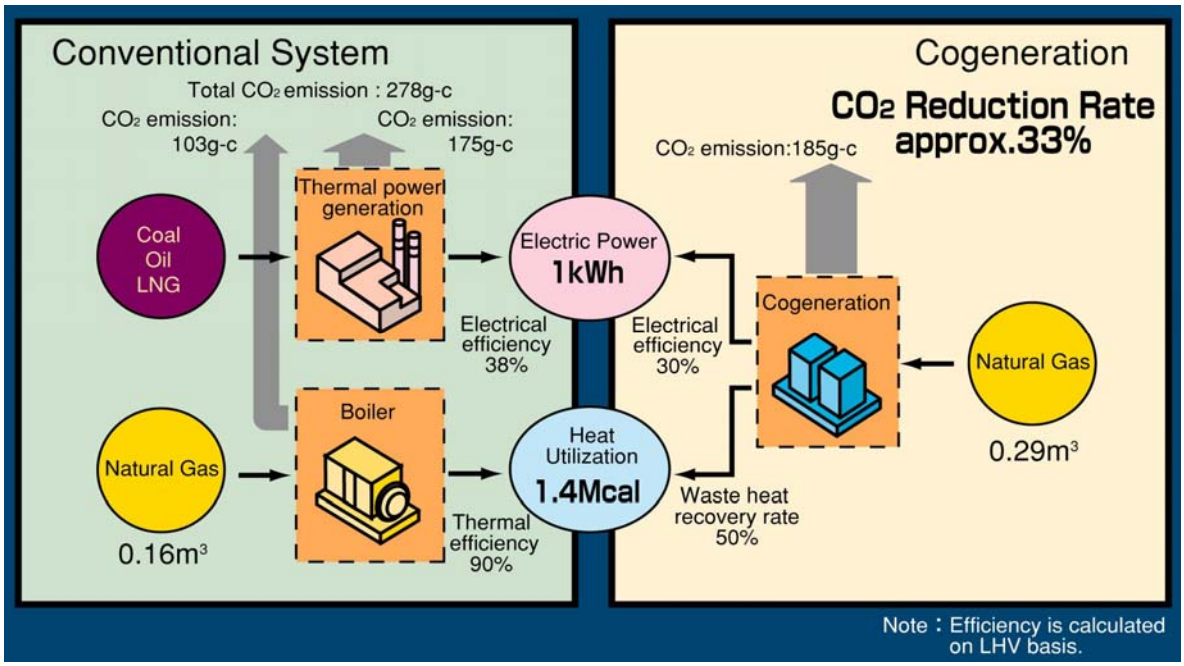


Figure 1.5 : Conventional System Compared to Cogeneration (CHP) System in terms of CO2 Reduction Rate

Figure 1.5 above explained the reduction of CO2 rate up to 33% for CHP system compared to the conventional separate power and heat systems.

1.7 Installed CHP in Malaysia

Approximately 900 MW of small to medium sized CHP licensees has been issued in Malaysia. CHP is used in the selected Independent Power Producer (IPP)'s, chemical plants and District Cooling systems like the one operating at the Kuala Lumpur International Airport (KLIA) in Sepang, Selangor. Most of the licensees were issued in the nineties, when Malaysia lacked power capacity and implemented a number of IPP's.

Figure 1.6 below shows the status of installed CHP capacity over total power generation capacity. It can be seen that Malaysia has about 6% of installed CHP capacity over total power generation and in par with Japan and United Kingdom. It also can be summed up that country like France that most of its power generated is from nuclear power plants has the lowest installed CHP capacity. Denmark has the highest installed CHP capacity of 50% because of the country's major focus and interest are in the Demand Side Management and Energy Efficiency programs.

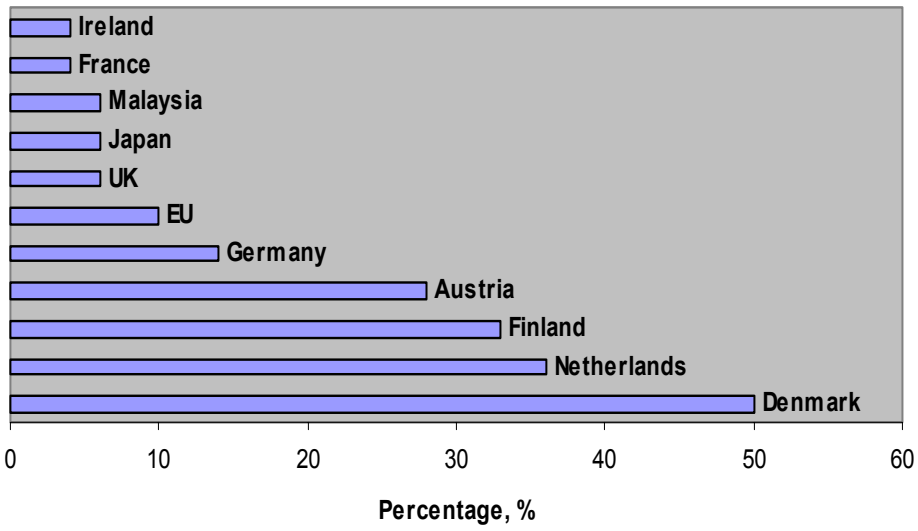


Figure 1.6 : Installed CHP capacity over Total Power Generation Capacity

1.8 Market for CHP Technologies in Malaysia

Below are the market for CHP technologies and its characteristics and suitability for Commercial and Industrial sector in Malaysia.

1. Reciprocating Gas Engines in Commercial Sector
   - High electrical efficiency (over 36%)
   - Fluctuating load for lighting and HVAC (heating/ventilation/air conditioning)

2. Gas Turbines better suit to Industrial Sector
   - Stable thermal and electrical demand with steam utilization
   - Longer operating hours, lower energy cost

3. Emerging technologies
    - Micro Gas Turbine engines
    - Fuel Cell (PEFC)

In the small to medium sized CHP market the steam turbines is typically imported from EU, USA, China and Japan and the boiler is manufactured locally by Malaysian company.

1.9 Key Players of CHP Market in Malaysia

The government departments, Economic Planning Unit (EPU) of Prime Minister Department, Energy Commission, Ministry of Energy Communication and Multimedia (MECM) are the main drivers in developing the policy and providing incentives for CHP plant. The utilities Tenaga Nasional Berhad (TNB), Sabah Electricity and Sarawak Electricity are buying the excess power from the IPP and CHP plant.

1.10 Legislation and Programs Promoting CHP

Since the Independent Power Producer development in the nineties, no direct policy and legislation has been promulgated to promote CHP. CHP has only been indirectly supported in the energy efficiency and biomass power measures initiated in connection with the Eight Malaysian Plan (The Malaysian plan for the period 2001 to 2005). Malaysia started its restructuring of the electric power industry in 1990 when the Parliament passed into the Electricity Supply Act of 1990. Then National Electricity Board was corporatised into a wholly-owned Government company, Tenaga Nasional Berhad (TNB) with regulatory oversight by the Suruhanjaya Tenaga (ST). TNB that was privatised in 1992 allowed the private sector to own

about 30 percent of TNB when the paid-up capital was enlarged. This was quickly followed by the entry of independent power producers or IPPs, majority owned by the private sector, from late 1994. Today, around 35 percent of total installed generation capacity are owned and operated by independent power producers or IPPs.

1.11 Importance of CHP to Malaysia

There are a number of advantages associated with the introduction of CHP plants to industries, the more obvious ones being listed below:

i. National Grid

Part of the demand on the Grid can be met by the manufacturing sector itself, thus reducing the stress on the Central Electricity Utilites to expand to meet industrial sector demand. Downstream effects of this are:

a) The risk of over-capacity on the Central Electricity Utilities will be reduced, as part of this risk is now carried out by CHP plant operators,

b) Conservation of capital by the Central Electricity Utilities. This can be used to improve profitability and upgrade the current system to increase reliability and quality of service,

c) Reduction in costs to service borrowings by Central Electricity Utilities to finance capital investment projects.

d) In the case of CHP plants that can export excess electricity, this will provide a wider pool of generating capacity for providing power into the National Grid. Experience in countries, e.g. Denmark, where distributed generation has been introduced have shown that if the pool of CHP plants is

big enough, the CHP plants as a group can attain reliabilities comparable with power plants solely dedicated to electricity production.

ii. Energy Efficiency

The energy intensity of the manufacturing industrial sector in Malaysia is among the countries with the highest ratios, and compare unfavorably with countries at a similar stage of economic development. CHP plants in industries will in part assist in lowering this ratio to a level comparable with most other nations. The real economic cost of industrial input will also be reduced accordingly with long-term benefit to the national economy.

iii. Greenhouse Gas (GHG) Emissions

Malaysia is one of the signatories to the Kyoto Protocol, which formally came into effect on 16 Feb 2005. There is an obligation on the part of signatories to the Kyoto Protocol to co-operate on a global scale to reduce the sum total of GHG emissions to a tolerable level. The implementation of CHP will be a step that will help to realize this aim.

1.12 Objective of the Study

This study was carried out to ascertain the economic and financial viability of introducing Combined Heat and Power (CHP) into the manufacturing sector mainly in Pulp and Paper Industry. As Natural Gas is an indigenous product of the petroleum industry in Malaysia, and it is the intention to encourage the widespread of Natural Gas in Malaysia for various reasons, this study is focused on CHP plants fired on Natural Gas only.

As we can see the benefits of CHP and the measures taken by the government, it is worth to investigate the potential of implementing CHP in Malaysian Industries. Thus the objectives of this work are as penned below;

- To Analyze Cost Effectiveness and Prospects of CHP for Pulp & Paper Mill Industry
- To Identify Suitable CHP Technology for Pulp & Paper Mill Industry
- To identify barriers of implementing CHP in the Malaysian Industry

The raw data from energy audits of PTM were used in the case study and analysis and the evaluations were done using software called RETScreen CHP Project Model.

1.13 Expected Benefits of the Study

The outputs of this study will also be used as general frameworks to the Malaysian Industry in identifying and justifying CHP options into their plant. The CHP options can be executed by the industries with their personal technical and economical preferences. The industries do not have to spend time in investigating the best technology towards energy efficiency but just spend their time efficiently in planning for the financial support and investment strategy. It will also encourage the Malaysian Industry to implement CHP options by giving the cost effectives analysis that can prove higher efficiency compared to conventional power generated system and be much more economical because the savings they generated.