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.
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I am also indebted to Pusat Tenaga Malaysia (PTM) for assisting me to complete this project and special thanks for their willingness to participate me into their Energy Audit in Penang.

My fellow postgraduate students should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members and most of all, my loving husband.
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**

# TABLE OF CONTENT

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td></td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>vi</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td></td>
<td>xv</td>
</tr>
</tbody>
</table>

1 STATUS OF COMBINED HEAT AND POWER IN INDUSTRIAL SECTOR IN MALAYSIA

1.1 Introduction 1
1.2 Malaysian Energy Trends, 1990-2003 2
1.3 Malaysian Final Energy Demand, 1990-2003 3
1.4 Malaysian Electricity Demand and Supply, 1990–2003 3
1.5 Market Growth Forecast 5
1.6 Overview of Combined Heat and Power (CHP) 6
1.7 Installed CHP in Malaysia 8
1.8 Market for CHP Technologies in Malaysia 9
1.9 Key Players of CHP Market in Malaysia 10
1.10 Legislation and Programs Promoting CHP 10
1.11 Importance of CHP to Malaysia 11
1.12 Objective of the Study 12
1.13 Expected Benefits of the Study

2 INTRODUCTION TO COMBINED HEAT AND POWER

2.1 Introduction
2.2 CHP Efficiency
2.3 Power to Heat Ratio
2.4 CHP Technologies
  2.4.1 Gas Turbine
  2.4.2 Steam Turbine
  2.4.3 Reciprocating Engines
  2.4.4 Microturbines
  2.4.5 Fuel Cells
  2.4.6 Installed Cost
  2.4.7 O&M Cost
  2.4.8 Start up Time
  2.4.9 Availability
  2.4.10 Thermal Output
  2.4.11 Efficiency
  2.4.12 Emission
2.5 Conclusion

3 METHODOLOGY

3.1 Typical Energy Project Implementation Process
3.2 RETScreen Software Overview
3.3 Financial Analysis
  3.3.1 Financial Feasibility Indicator
3.4 Greenhouse Gas (GHG) Emission Reduction Analysis
  3.4.1 GHG for generating electricity
  3.4.2 GHG for heating and cooling

4 POWER IN PULP AND PAPER INDUSTRY IN MALAYSIA
4.1 Introduction
4.2 Pulp and Paper in Malaysia
4.3 Pulp and Paper Energy Consumption
4.4 Pulp and Paper Processes and Technology
4.5 Pulp and Paper Power to Heat Ratio
4.6 Conclusion

5 PULP AND PAPER ENERGY AUDIT REPORT

5.1 Energy Audit Report
5.2 Operational Review of the Factory
5.3 Base Case Load and Network Design
   5.3.1 Heating Project
   5.3.2 Cooling Project
   5.3.3 Power Project
5.4 Energy Model
5.5 Power to Heat Ratio Calculation
5.6 Proposed Case Equipment Selection
   5.6.1 CHP Technology for Factory A
   5.6.2 CHP Technology for Factory B
   5.6.3 CHP Technology for Factory C
5.7 Conclusion

6 RESULTS AND DISCUSSIONS
6.1 Assumption for Case Study – General Parameter
6.2 CHP Energy Efficiency
6.3 Project Cost and Saving Income
6.4 Financial Evaluation and Greenhouse Gas (GHG) Emission Reduction Results
   6.4.1 Internal Rate of Return (IRR)
   6.4.2 Simple Payback Period (SP)
   6.4.3 Net Present Value
   6.4.4 GHG Reduction Cost
7 CONCLUSION AND RECOMMENDATIONS

7.1 Conclusions

7.2 Advantages of Introducing CHP to the Malaysian Industry
   7.2.1 High Energy Efficiency
   7.2.2 Industrial Customer Cost Saving
   7.2.3 Outage protection and other features of CHP
   7.2.4 Air Emissions Reductions
   7.2.5 Electric System Benefits

7.3 Barriers Identified

7.4 Recommendations and Proposed Future Works

REFERENCES
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>GDP, Population, Primary Energy Supply, Energy Demand and Electricity Demand (1990 – 2003)</td>
<td>2</td>
</tr>
<tr>
<td>2.1</td>
<td>Measurements of Efficiency of CHP Systems</td>
<td>16</td>
</tr>
<tr>
<td>2.2</td>
<td>Summary of CHP Technologies</td>
<td>20</td>
</tr>
<tr>
<td>2.3</td>
<td>Summary of Typical Cost and Performances Characteristics by CHP Technology Type</td>
<td>21</td>
</tr>
<tr>
<td>2.4</td>
<td>Summary of Gas Emissions for CHP Technology</td>
<td>31</td>
</tr>
<tr>
<td>3.1</td>
<td>Global Warming Potential of greenhouse gas</td>
<td>42</td>
</tr>
<tr>
<td>4.1</td>
<td>Malaysian Industrial Energy Consumption in 2003</td>
<td>50</td>
</tr>
<tr>
<td>4.2</td>
<td>Steam and Electric Power Consumption for Typical Pulp and Paper Processes</td>
<td>52</td>
</tr>
<tr>
<td>5.1</td>
<td>Operational Review of Factory A, B and C</td>
<td>55</td>
</tr>
<tr>
<td>5.2</td>
<td>Heating Project Base Case Data</td>
<td>56</td>
</tr>
<tr>
<td>5.3</td>
<td>Cooling Project Base Case Data</td>
<td>57</td>
</tr>
<tr>
<td>5.4</td>
<td>Power Project Base Case Data</td>
<td>58</td>
</tr>
<tr>
<td>5.5</td>
<td>Power to Heat Ratio</td>
<td>59</td>
</tr>
<tr>
<td>5.6</td>
<td>CHP Technology Power to Heat Ratio Range</td>
<td>60</td>
</tr>
<tr>
<td>5.7</td>
<td>Equipment Data for Factory A</td>
<td>61</td>
</tr>
<tr>
<td>5.8</td>
<td>Equipment Data for Factory B</td>
<td>62</td>
</tr>
<tr>
<td>5.9</td>
<td>Equipment Data for Factory C</td>
<td>63</td>
</tr>
<tr>
<td>6.1</td>
<td>General Parameter</td>
<td>66</td>
</tr>
<tr>
<td>6.2</td>
<td>Proposed CHP Project Energy Efficiency</td>
<td>67</td>
</tr>
</tbody>
</table>
6.3 Project Cost and Saving Income Summary 68
6.4 Financial Viability 69
7.1 Reasons for not going ahead with CHP 78
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Trends in GDP, Primary Energy Supply and Final Energy Demand</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>Final Energy Demand by Sector (1990 – 2003)</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>Electricity Consumption by Sectors (1990 – 2003) in ktoe</td>
<td>4</td>
</tr>
<tr>
<td>1.4</td>
<td>Conventional System Compared to Cogeneration (CHP) System in terms of Energy Conservation Rate</td>
<td>7</td>
</tr>
<tr>
<td>1.5</td>
<td>Conventional System Compared to Cogeneration (CHP) System in terms of CO2 Reduction Rate</td>
<td>7</td>
</tr>
<tr>
<td>1.6</td>
<td>Installed CHP capacity over Total Power Generation Capacity</td>
<td>9</td>
</tr>
<tr>
<td>2.1</td>
<td>CHP versus Separate Heat and Power (SHP) Production</td>
<td>15</td>
</tr>
<tr>
<td>2.2</td>
<td>CHP Efficiency Calculation</td>
<td>17</td>
</tr>
<tr>
<td>2.3</td>
<td>Equivalent Separate Heat and Power Efficiency</td>
<td>18</td>
</tr>
<tr>
<td>2.4</td>
<td>Power to Heat Ratio for CHP</td>
<td>19</td>
</tr>
<tr>
<td>2.5</td>
<td>Gas Turbine Schematic</td>
<td>22</td>
</tr>
<tr>
<td>2.6</td>
<td>Steam Turbine Schematic</td>
<td>23</td>
</tr>
<tr>
<td>2.7</td>
<td>Reciprocating Engines Schematic</td>
<td>24</td>
</tr>
<tr>
<td>2.8</td>
<td>Fuel Cell Schematic</td>
<td>26</td>
</tr>
<tr>
<td>3.1</td>
<td>Flow of a typical project analysis</td>
<td>33</td>
</tr>
<tr>
<td>4.2</td>
<td>Pulp and Paper Factory in Malaysia</td>
<td>49</td>
</tr>
<tr>
<td>4.3</td>
<td>Pulp and Paper Energy Consumption</td>
<td>50</td>
</tr>
<tr>
<td>5.1</td>
<td>Operating Hour and Net Production Output for Factory A, B and C</td>
<td>55</td>
</tr>
<tr>
<td>5.2</td>
<td>Power Gross Average Load Graph</td>
<td>58</td>
</tr>
<tr>
<td>6.1</td>
<td>Internal Rate of Return Graph</td>
<td>70</td>
</tr>
</tbody>
</table>
6.2  Simple Payback Period Graph  71
6.3  Net Present Value Graph  72
6.4  GHG Reduction Cost Graph  73
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)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP at 1987 prices (RM million)</td>
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<td>231674</td>
</tr>
<tr>
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<td>22636</td>
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<td>23935</td>
<td>24447</td>
<td>24967</td>
</tr>
<tr>
<td>Primary Energy Supply (ktoe)</td>
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<td>50452</td>
<td>50749</td>
<td>54194</td>
</tr>
<tr>
<td>Final Energy Demand (ktoe)</td>
<td>13217</td>
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</tr>
<tr>
<td>Electricity Demand (ktoe)</td>
<td>1715</td>
<td>3375</td>
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<td>4815</td>
<td>5263</td>
<td>5694</td>
<td>5922</td>
<td>6313</td>
</tr>
<tr>
<td>Electricity Demand (GWh)</td>
<td>19932</td>
<td>39225</td>
<td>43897</td>
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<td>53187</td>
<td>55912</td>
<td>60299</td>
<td>63043</td>
<td>66991</td>
<td>71159</td>
</tr>
</tbody>
</table>

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.

![Figure 1.2: Final Energy Demand by Sector (1990 – 2003)](image)

1.4 Malaysian Electricity Demand and Supply, 1990 - 2003

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

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