THE POSSIBILITY OF THE COMBINED HEAT AND POWER (CHP) USAGE
AT PALM OIL PROCESSING PLANT

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DEDICATION

Especially for my beloved parents,

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Also to my brother and sisters:

Turipah
Rohaya
Halipah Pauziah
Rusiyah
Rusinah
Mustaffa

And not forgetting to all my nieces and nephews

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Abstract

Combined Heat and Power (CHP) is a generation of electrical and thermal energy in a single process. In simple words, it could be explained as making electricity and use the rejected heat to fill the thermal requirement. The heat, which is normally lost in the production one form of energy, will be recovered to generate another form of energy. The making use of this waste heat differentiates CHP from conventional electric power generation. Sampadi Palm Mill, Lundu Sarawak is a self-sufficient industry as far as energy utilization is concerned. It is equipped with steam turbine, boiler and diesel engine. They used palm fruit waste as a boiler fuel. Through observation, there is no heat exchanger use to convert the heat to useful purpose. Therefore, this study is done to examine whether Sampadi Palm Mill is possible to utilize CHP or not. The analysis involve in this study are boiler analysis, thermal efficiency, steam turbine analysis and load factor analysis. The boiler analysis, thermal efficiency and steam turbine analysis are used to measure the capability of the existing steam turbine and boiler system. Meanwhile, the electric and thermal load factor analysis is used to indicate the possibility of CHP at Sampadi Palm Mill. The finding of lower electric and thermal load factor, which is 2.51% and 1.96% respectively shows that Sampadi Palm Mill is not a good candidate for CHP.
Abstrak

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NOMENCLATURE

CV - Calorific value
hi - Enthalpy from initial
ho - Enthalpy at exhaust steam
hs - Enthalpy of steam produced
hw - Enthalpy of feed water
mf - Fuel consumption rate
ms - Steam flow rate
P3 - Pressure at pump entrance
P4 - Pressure at pump exit
Qin - Rate of energy input
Qout - Rate of energy output
Qs - Heat supplied to the fluid
Sr - Entropy of the fluid
Sfg - Entropy of vaporization
Sg - Entropy of gas
T - Temperature
vf - Specific volume of water
WP - Pump work input
WT - Turbine work output
x - Dryness fraction
Greek Letter

\( \eta_B \) - Boiler efficiency

\( \eta_{TG} \) - Turbine generator overall efficiency

\( \eta_{TH} \) - Thermal efficiency of cycle
CHAPTER 1

INTRODUCTION

1.1 The Combined Heat and Power (CHP)

Combined heat and power (CHP) is a generation of electrical and thermal energy in a single process. The term CHP is synonymous with “cogeneration” and “total energy”. In the 1970's, President Jimmy Carter explains the word “cogeneration” as using a steam boiler to generate electricity and heat simultaneously [Kaarsbergh & Elliot, 1999]. But nowadays, the wider ranges of technologies in modern systems make CHP plant more efficient and versatile.

Generally, CHP is the combined production of electrical or mechanical energy and heat. The heat can be in the form of hot gases, hot liquids, or process steam. In simple words, it could be explained as generating electricity and use the rejected heat to fill the thermal requirement. The combined generation of work whether electrical or mechanical and process heat provides a better overall utilization of the fuel used in a plant. According to Reicher [1999], CHP plant converting as much as 85% the fuel into usable energy.

The basic element of CHP systems is an engine, which driven an electrical generator and known as prime mover. The heat generated in the process of driven electrical generator is utilized through suitable heat recovery equipment for a variety of purposes including industrial processes, community heating and space heating.
Besides that, CHP systems also consist of integral heat recovery equipment and control or monitoring system.

According to **Figure 1.1**, CHP generation allows the optimum use of the input energy available, converting around 80% of the fuel into useful electricity and heat. The use of conventional power generation provides power at an efficiency of about 35% only. Overall, CHP can result up to 85% of the primary fuel energy being converted to electricity and usable heat compared to typical 35% efficiency with conventional generation. Usually, there is a lot of energy lost in separate operation of electrical energy generation. But CHP can recover it in which using the energy to produce steam, cooling or can be used to displace heat normally produced by steam boiler. CHP is an addition to existing boiler heat and mains electricity supply.

![Figure 1.1 The Comparison between Conventional Power and CHP Generation](http://www.pdfsplitmerger.com)

[Combined Power System Limited, 1999]
1.2 The Component of CHP Systems

The basic components of any CHP systems are prime mover, generator, waste heat recovery system and operating control. The prime mover is an engine or turbine, which, through combustion, produces mechanical energy. It is most important part in the CHP system. The gas turbine, the reciprocating engine and the steam turbine are the most commonly used as prime movers in a CHP system.

(i) Gas Turbine

For large-scale applications, such as in industrial, the gas turbine is usually selected as the prime mover. Gas turbine engines are mechanically simpler and require less frequent maintenance. It can be switched from natural gas to diesel fuel to take advantage of price fluctuation and backup fuel requirements. In addition, it can be adjusted for other fuel oils and occasionally, organic by-products of industrial processes such as “black liquor” from pulp and paper mills.

(ii) Reciprocating Engine

The selection of a reciprocating engine as the prime mover is usually made for a commercial installation. This engine is most advantageous where there is a high-demand for electricity and low heat outputs. Reciprocating engine generators have the highest maintenance requirements. This type of engine is not flexible with respect to its fuel requirements. The fuel requirements are gasoline and diesel. Occasionally natural gas engines can be adapted to switch between natural gas and propane as an
alternate fuel. The air pollution regulations may impose greater constraints on these engines than gas turbines.

(iii) Steam Turbine

High-pressure steam is the requirement for the use of a steam turbine with CHP. Typically, the steam turbine is used for large installations. It requires even less mechanical maintenance than gas turbines since it has no combustion equipment attached. Steam turbines are limited only by the fuel for their steam source. In addition, coal, wood, waste, peanut shells, any suitable biomass and incinerated municipal waste can be used to generate steam for steam turbines. It is classified by mechanical arrangement, steam flow direction, steam cycle and number of exhaust flows of a condensing unit.

The selection of the prime mover depends on the amount of waste heat it makes available and the temperature of this waste heat. CHP systems are designed to use as much of this waste heat as possible and to use the available waste heat temperature. Figure 1.2 illustrates the schematic diagram of separate steam and electric power plant. Meanwhile, Figure 1.3 and 1.4 illustrate the power generation of back-pressure steam turbine and gas turbine with waste heat boiler. These three types of figures compare the steam turbine and gas turbine CHP systems with the separate generation of steam and thermal energy. The diesel system is similar in arrangement to the gas turbine system.
**Figure 1.2** Schematic diagrams of separate steam and electric power plants. [Thumann, 1991]
The generator converts the mechanical energy to electric energy. The waste heat recovery system is one or more heat exchangers that capture exhaust heat or engine coolant heat and convert that heat to a useful form. The operating control systems insure that the individual system components function together.

1.3 The Configuration of CHP Systems

There are several types of CHP systems configuration. Nowadays, the ranges of CHP systems configuration are;
(i) **Boiler Systems with Steam Turbines**

In the traditional CHP configuration, a boiler generates steam from burning fuel or utilizing waste heat from an industrial process, such as a furnace. Some or all of the steam turns a steam turbine that generates electricity. The steam then satisfies thermal requirement such as space heating or industrial process. This CHP configuration still dominates industrial CHP.

(ii) **Combustion Turbine or Reciprocating Engine with Heat Recovery**

In this configuration, a combustion turbine or engine generates electricity or mechanical energy. The heat in the exhaust and in the cooling water and oil generates steam in a boiler. Such systems will capture a greater share of the CHP market in the future. Reciprocating engines are the dominant technology for smaller systems with an average installed size of less than 1 MW.

(iii) **Combined Cycle Systems**

In a combined cycle system, a steam turbine is used as part of a combustion turbine system in order to increase the electricity produced. The electricity fraction of usable energy in these systems frequently exceeds the thermal output. While these systems account for only a small number of industrial CHP systems, they are significant in terms of capacity and are the dominant configuration for new merchant power plants. These independently owned power generation facilities produce both electrical and thermal energies.
(iv) Fuel Cell with Heat Recovery

Fuel cells are an emerging technology that converts chemical energy directly into electricity, producing very little pollution. Heat is byproduct of the reaction, and can be covered in much the same way as with turbines and reciprocating engines. This technology will gain an increasing market share in coming years as new types of fuel cells enter the marketplace. In 1998, the first proton exchange membrane fuel cell was sold and by 2000, several other types of fuel cells could be on the market. [Reicher, 1999]

1.4 Basic Thermodynamics Cycles

Normally, there are two most likely processes for consideration. These two types of CHP system that can be best applied are topping and bottoming cycle. The topping unit in which the primary energy is used to produce electricity and rejected heat is used to satisfy the needs of relatively low-temperature thermal process. Meanwhile, the bottoming unit in which the energy is used first to satisfy the thermal demands of a high-temperature process and rejected heat is then used to produce power. In the near term, topping units offer more opportunity for energy savings because of the ready availability of appropriate technologies and because low temperature processes account for the majority of total thermal demands.

1.4.1 Topping Cycles

The electricity or mechanical power is produced first, and then heat is recovered to meet the thermal loads of the facility. Topping cycles also could be referred as
Rankine cycles. This type of cycle is a basic cycle for vapor liquid system typical of steam power plants. It provides a real world outlet for waste heat recovered from any process or generation situation as Figure 1.5. Generally, topping cycles are found in facilities, which do not have extremely high process temperature requirements.

Figure 1.5 Topping Cycle [Thumann & Mehta, 1991]

1.4.2 Bottoming Cycles

In the bottoming cycles [see Figure 1.6], thermal energy is produced directly from the combination of fuel. Energy usually takes the form of steam that supplies process-heating loads. The waste heat is recovered and used as an energy source to produce electric or mechanical power. Generally, this type of cycles could be found in industrial plant that have equipment with high-temperature heat requirements such as steel reheat-furnace, clay and glass kilns and aluminum remelt furnace.
1.5 The Advantages of CHP

The CHP is the most efficient, cost-effective and environmentally friendly way to provide heat and power from one primary fuel. CHP represents a strategy for energy to meet environmental goals while reducing operating cost which resulting in a cleaner environment, more competitive companies and economic growth, increase job security and also more efficient use of energy resources. The CHP system can make use about two-thirds of the waste heat. CHP can provide a highly efficient method of generating electricity and heat and also makes lower cost energy for factories in more competitive manner.

The using of CHP system in industry and commercialization can avoid transmission and distribution losses. It reduces the need to expand electricity
transmission grid. Actually, long distance electrical transmission is expensive due to
the need for expensive transformers, erection and maintenance costs. CHP plant is
interesting option for supplying electricity and heat to public sector and industry. The
interest growth is due to the low initial costs, short time needed for construction and
economical operation.

CHP has great potential for the environment. The current mix of CHP
installations achieves a reduction over 30% in carbon dioxide emissions in
comparison with generation from coal-fired power stations and over 10% in
comparison with gas fired combined cycles gas turbine. It has been identified as an
important national strategy to reduce the emission of greenhouse gases while
promoting economic growth. [Kaarsbergh & Elliot, 1999]

1.6 The Development of CHP

CHP is well-established technology with a long history. Many manufacturing plants
operated CHP facilities at the turn of the 19th century, most abandon. However, some
industries still continue to operate their CHP facilities such as pulp and paper and
petroleum refining. CHP was already applied in industry several decades ago, but the
drastic oil price rises of the 70's and the energy crisis that attract more on CHP. Some
new CHP have been constructed during late 1970's and early 1980's. In 1995, CHP
provide 42 GW of electricity generation capacity in U.S. The CHP with share of
electric generation can grow if the policies to promote CHP are instituted. [Reicher,
1999].
Nowadays, CHP project likely will occur at larger industrial plants, which have large steam loads and at existing district energy facilities. Sometimes, a back-pressure turbine can add to an existing steam system and in other case, an existing boiler may be repowered with a combustion turbine. As time progresses, small industrial, institutional and commercial facilities will begin to make up a greater part of the new capacity.

Growing environmental concerns also should advance the CHP market. By replacing older generating equipment with cleaner and more efficient systems, CHP will reduce carbon dioxide and other pollutants, including NO\textsubscript{X}, while increasing thermal efficiency. In contrast, the traditional "end-of-pipe" pollution control techniques usually reduce the thermal efficiency of the energy generation equipment, increasing carbon dioxide emissions.

1.7 The Marketplace of CHP

In the late 1970's, Public Utilities Regulatory Policy Act (PURPA) was renewed the interest in CHP, which included measures to promote CHP as an energy efficient technology. PURPA played a critical role in moving CHP into the marketplace. Many CHP facilities are owned by independent companies. The CHP marketplace is following the changes in the electric industry and technology. According to Reicher [1999], the marketplace for industrial CHP can be divided into the following segments;