ANALISIS TEKNIKAL DAN KEWANGAN BAGI LOJI KUASA DWI-PENJANAAN BIOJISIM

(TECHNICAL & FINANCIAL ANALYSIS OF BIOMASS COGENERATION POWER PLANT)

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Finally, I wish to thank my parents and my friends who had supported and motivated me throughout the completion of this project.

Thank you,

RAMESH A/L YANKI NAIDU
4th MARCH 2005

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ABSTRACT

This report presents the technical and financial analysis of biomass cogeneration power plant. The term 'biomass' means any organic matter that is available on a renewable or recurring basis. Cogeneration means simultaneous generation of two different forms of useful energy using one single primary source. Technical and financial analysis (TFA) will be done using TFA model, version 2 from COGEN 3 software.

This analysis was done on two different power plants. They are Sungei Dingin Palm Oil Mill (2 MW_e plant), which implemented by the Kumpulan Guthrie Berhad, located in Kulim, Kedah and Rice Husk Fired Cogeneration Plant situated in Thailand. During the comparison on the different power plants been carried out, the analysis on technical and financial must take into account. The comparison between power plant using fresh fruit bunch and rice husk with the baseline or power plant using current energy supply also been carried out.

TFA model is a pre-evaluation of cogeneration projects. It can calculate the financial performance of a cogeneration project compared to electricity purchase and thermal energy (steam/hot water) generation in boiler to the host facility.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Biomass represents a healthy sector in Malaysia, which is the largest palm oil producer in the world. The palm oil industry, who is selling the production in dollars has not been affected by the crisis and is driving the market with more than 300 palm oil mills in operation producing an estimated 19 million tons of crop residues per year.

In Malaysia, crop residue utilization for power generation is dominated by one single sector: the palm oil industry. Empty fruit bunches, shells, fibre, and even palm oil mill wastewater can be used for the generation of steam and electric power. There are some 281 palm-oil mills in operation (1995) with an aggregate installed capacity of around 200 MWe. All this capacity is installed to meet own demand (captive power). For 1995, it was estimated that a total of 42 million tons of fresh fruit bunches were produced in Malaysia. This translates to around 17 million tons of waste. For low-pressure systems with an assumed conversion rate of 2.5 kg of palm oil waste per kWh, potentially 7,000 GWh could be theoretically generated. Also for empty fruit bunches however, alternative uses (such as Medium Density fibreboard) are becoming available. These competing alternatives may eventually result in waste shortages at palm-oil mills. These shortages, combined with the stricter enforcement of environmental standards, will lead to a call for more efficient (high pressure ~ 8 MPa), environmentally friendly cogeneration equipment. Retrofitting existing palm-oil mills with (partly) new cogeneration equipment is expected to become an interesting commercial opportunity. Boilers typically have a rate capacity of 25-30 t/h. for power generation; turbines are usually not larger than 1-1.5 MWe, practically always in a backpressure set up with the first priority for heat generation for sterilization purposes.

While milling the paddy, rice mills produce rice husk, which can be considered as fuel for heat and power generation provided the waste volume, is sufficient and regular. With a total volume of rice paddy amounting to 2.2 million tons (1994) and for 22 % consisting of rice husk, a theoretical volume of 0.47 million tons of rice husks would be available. So far, experiences in Malaysia with the utilization of rice residues for heat and power generation have remained quite limited. A central problem is that paddy needs to

Table 1.1 Typical biomass fuel characteristics in ASEAN

Sector	Residues	Heating Value (MJ/kg)	Moisture Content (% wet basis)	Mineral Content (% dry basis)
Rice	Rice husk	13 - 14	9 – 12	20
Sugar	Bagasse	7 - 8	45 - 50	3 - 4
Palm Oil	Fresh fruit bunch	7 – 8	45 – 50	5.5
	Fibers	10 – 11	38 – 40	5.8
	Shells	17 – 18	22 – 25	2
Wood	Shavings, off-cuts, etc.	11 - 12	30 - 35	1 - 2

be dried as soon as it is delivered to the rice mill. This is only in the harvest season, while actual rice milling can be done all year round. This mean that required heat/power ratios for cogeneration will vary with the season. In addition, rice husk is a very difficult biomass for burning with a relatively low calorific value, high volatile matter content and high ash content. Actually, the high commercial value of the ashes (silica, sold in the metal industry) may provide more incentive to venture into cogeneration than the heat and power by themselves. Techno economically, cogeneration systems are only feasible for rice mills with a minimum production capacity of 5 tons per hour. [1]

The term ‘biomass’ means any organic matter that is available on a renewable or recurring basis (excluding old growth timber), including dedicated energy crops and trees, agricultural food and feed crop residues, wood and wood wastes and residues, aquatic plants, grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials. The typical characteristics of biomass fuels are shown in Table 1.1.

Cogeneration has widely applied in agro-industries such as sugar mills and palm oil mills. As the trend in the wood industries shift towards integrated wood complexes, cogeneration plants are being implemented increasingly in this sector too. In some cases, rice husk as well as coconut husks and shells, can also be used as a fuel to meet the energy demands of the plant to a certain extent while abating the environmental pollution associated with their disposal. If appropriate technologies are implemented, cogeneration.

Table 1.2 Typical specification of natural gas.

Heating Value MJ/m^3	CH_4 (%)	C_2H_6 (%)	CO_2 (%)	N_2 (%)
36 - 39	90 - 95	3 - 4	2 – 3	3 – 4

can not only render these agro-industries self sufficient in energy, but can also help them to earn profit by exporting excess energy to the national grid or to neighbouring countries. Typical specification of natural gas shown in Table 1.2.

Natural gas is a hydrocarbon (a compound of hydrogen and carbon) formed by the decomposition of vast numbers of microscopic plants and animals millions of years ago. Broken down by heat and the pressure of overlying rock, these organisms were transformed into oil and gas and stored in cavities beneath the surface of the earth. Typical natural gas characteristics:

- Mostly methane.
- Colourless, odourless and non-toxic.
- Lighter than air.
- As a gas in normal atmosphere.
- The rate of ignition at 5-15% of air’s volume.
- Complete combustion, leaves no residue.

The concept of using cogeneration method in Southeast Asia is not new. Prior to the economic crisis in the region that started in 1997, electricity demand and consumption in Southeast Asia was growing rapidly. After 1997, consumption growth declined but is expected to rise again due to rapid growth in energy demand. The need to develop new power plants to meet the growing demand is the driving force behind many regulatory and institutional changes that transforming the electricity sector in most countries in Southeast Asia. Respective governments have encouraged private involvement in power generation through cogeneration, renewable energy and waste to energy schemes.

This project was initially proposed for End-users/Co generators and for the Power Utility & National Economy. [2]

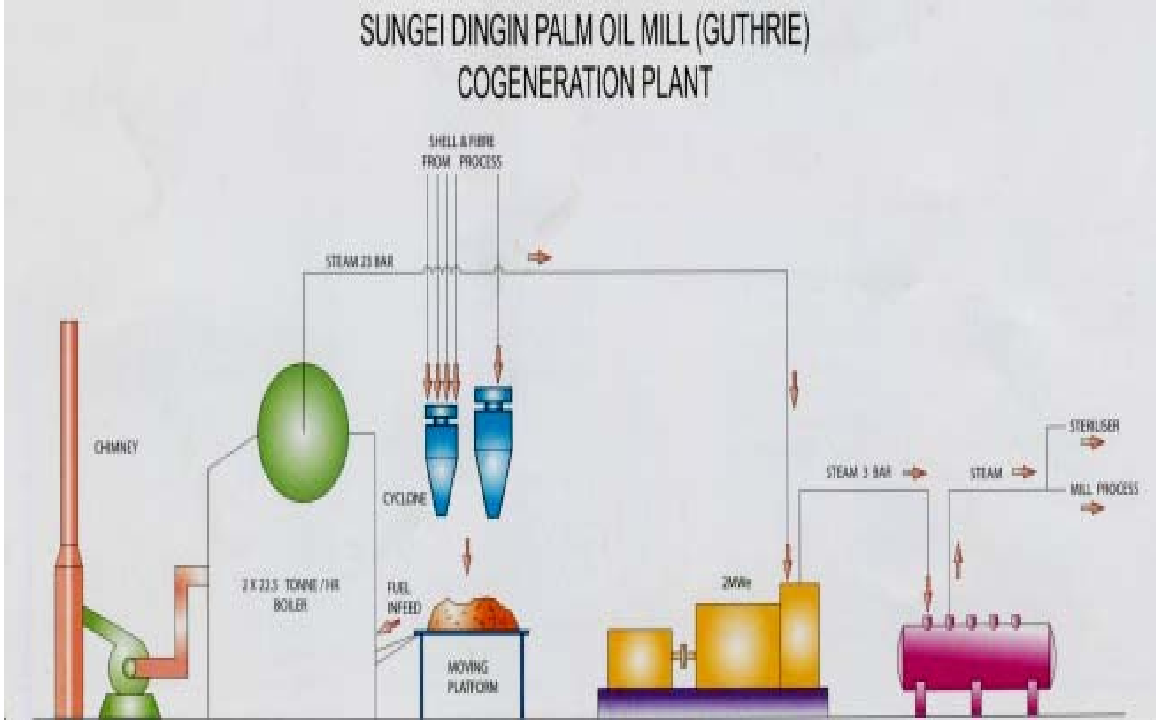

Figure 1.1 Sungei Dingin Palm Oil Mill technology

1.1.1 Sungei Dingin Palm Oil Mill Project

The Sungei Dingin Palm Oil Mill project (2 MW_e plant) is implemented by the Kumpulan Guthrie Berhad (KGB) in Malaysia. The plant is located in Sungei Dingin Estate, Karangan, Kedah, Malaysia. The total investment cost amounts to Euro 2.0 million (RM), excluding civil works and building foundations. The expected payback period is 5 years after commissioning. The plant consists of the following components (Refer Figure 1.1):

- Moving-floor Silo Unloading System;
- Combined Watertube-Firetube Steam boiler generating 2×22.5 tonnes/h at 23 bar and equipped with two Dynamic Watercooled Stepgrates;
- Multicyclone Dust Collectors;
- 2×2 MW_e back pressure turbo generators (1 running, 1 standby).

The boiler used by the Sungei Dingin Palm Oil Mill is Vyncke Boiler, as shown in Figure 1.2. The combustion technology used which was Dynamic Watercooled Stepgrade System, provides specific control of primary air for combustion. The

Figure 1.2: Vyncke Boiler

combinational boiler in the system provides 99 % dry steam and is able to respond to a sudden steam peak and maintain a stable pressure level.

The selection of the turbine is based on an efficient turbine which can supply power for process requiring 1600 kW, including domestic demand over 200 kW. The KKK steam turbines (Figure 1.3) have an isentropic efficiency of 66.5 % and that the back pressure system has a cycle efficiency of over 68 %.

Figure 1.3: KKK steam turbines

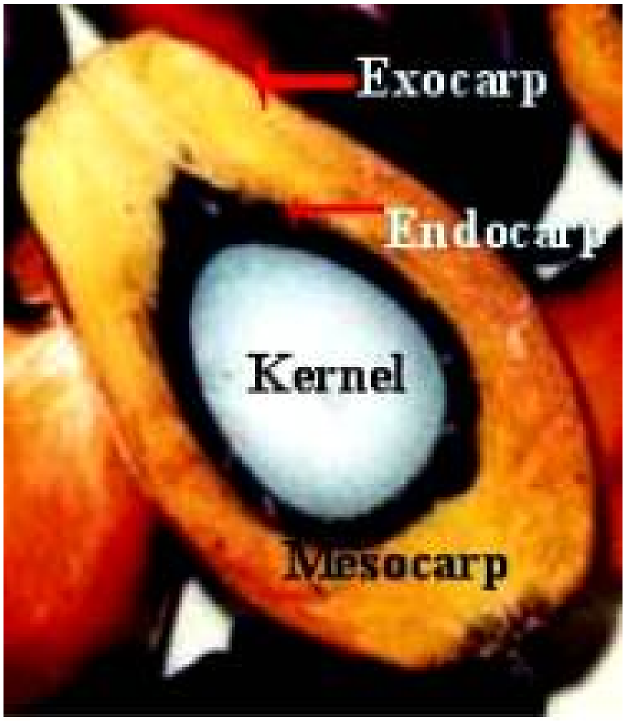

Figure 1.4: Oil palm fruit.

The 2 MW_e plant is self-sustaining and also provides extra electrical and steam capacity for their milling process. Fuel for the plant is shell and fibre. The main part harvested from oil palm is the fruit. Palm fruit grows in large bunch, weigh 20-70 kg, containing 400 to 2000 individual fruits. [3] The fruit consist of nut and mesocarp (fibre). Nut consists of shell and kernel. (Refer Figure 1.4)

1.2 PROBLEM STATEMENT

The term ‘biomass’ means any organic matter that is available on a renewable or recurring basis. Cogeneration is the use of single input of fuel to simultaneously produce useful electricity and heat from the same source, usually from one source. In the production of electricity, heat is normally wasted as exhaust. If the wasted heat from the electricity generation process can be reused, a large amount of fuel will be saved. During the comparison on the different power plants been carried out, the analysis on technical and financial must take into account. This analysis is going to be done using a Technical and Financial Analysis (TFA) software, by COGEN 3.

1.3 OBJECTIVE

The analysis was done on 2 MW Sungei Dingin Palm Oil Mill (Guthrie) Cogeneration Plant. The purpose of this investigation is to present the technical and financial data of biomass cogeneration power plant and to compare it with existing power plant. The comparison was done based on 3 MW Rice Husk Cogeneration Power Plant in Thailand.

1.4 SCOPE

This project's case study was done on existing power plant in Malaysia only. The analysis was done based on limitations of the TFA model. Modelling is done on a yearly basis, which gives the model limitations for detailed technical design of the cogeneration plant and how the plant will meet the energy requirements in the host facility. It is also assumed that the generation of electricity and thermal energy correspond in time with the demands for electricity and thermal energy in the host facility. Furthermore, only one cogeneration technology can be modelled. This means that it is not possible to model a combination of a diesel engine and boiler steam turbine cogeneration system. The COGEN 3 software can also be used to produce the performance and financial analysis of a proposed power plant and consider its feasibility and financial viability.

CHAPTER 2: LITERATURE REVIEW

Cogeneration means simultaneous generation of two different forms of useful energy using one single primary energy source. The most usual combination that can be seen are electrical (or mechanical) and thermal (heating or cooling). The definition of ‘Cogeneration’ also known as ‘Combined Heat and Power’ (CHP).

The objectives of COGEN 3 are to promote awareness and use of cogeneration in ASEAN, to promote proven, clean and efficient European cogeneration technologies and to create business opportunities for cogeneration plants using biomass, coal and gas as fuels. COGEN 3 is design for end-users and co generators. For end-users or co generators, cogeneration can reduces energy bills, increase profit from surplus electricity, additional profit from selling by-products (example: ash from rice husk burning) and increasing security of energy supply. For the power utility and national economy, it can save primary energy consumption, reduce transmission and distribution losses, less burden on national government for power generation investment and creating new market for local energy equipment suppliers or manufacturers.[4]

To use TFA, it requires knowledge of energy streams in energy plants, basic financing principles and the knowledge of using Excel. In this COGEN 3, it consists of technical, financial and environmental analysis, advice on technology selection and investment decisions, financial packaging, announcement of identified cogeneration projects in ASEAN and tools for development and evaluation of cogeneration projects.

In the convectional energy supply, boiler use fuel to produce thermal energy (Refer Figure 2.1). Electricity used from different source. For cogeneration energy supply, fuel used to generate electricity and thermal energy from the cogeneration power plant (Refer Figure 2.2).

TFA uses and benefits:

- for calculations of financial performance for cogeneration projects.
- consistency of energy uses
- comparison with electricity purchase and boiler for steam/hot water
- modelling of energy streams and cash flows on yearly basis
- black box approach to cogeneration systems

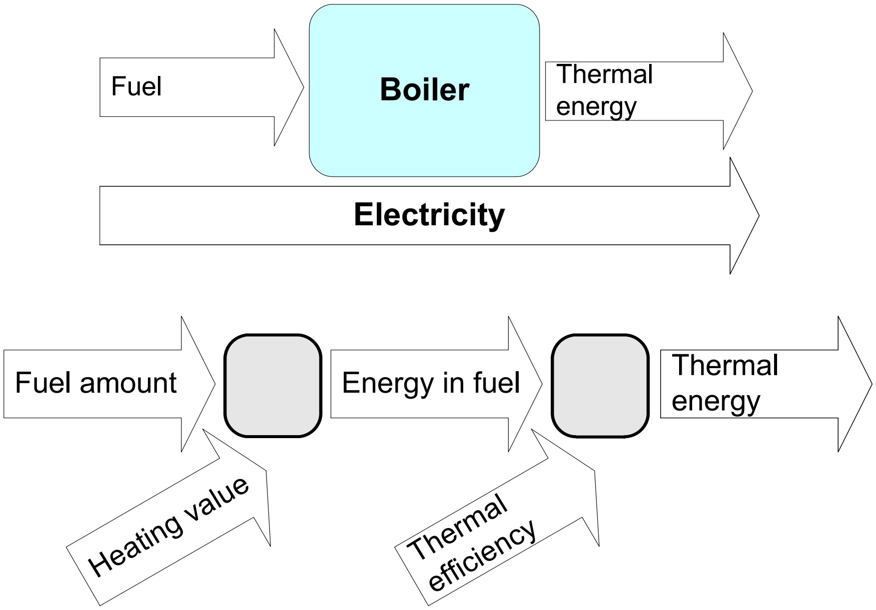

Figure 2.1: Convectional energy supply

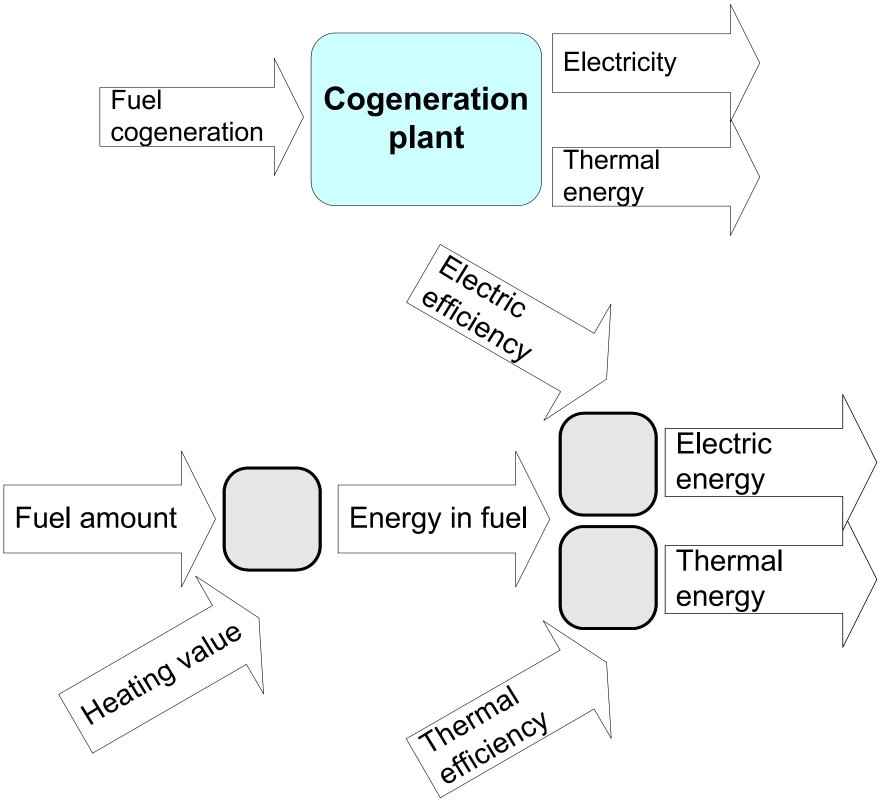

Figure 2.2: Cogeneration energy supply

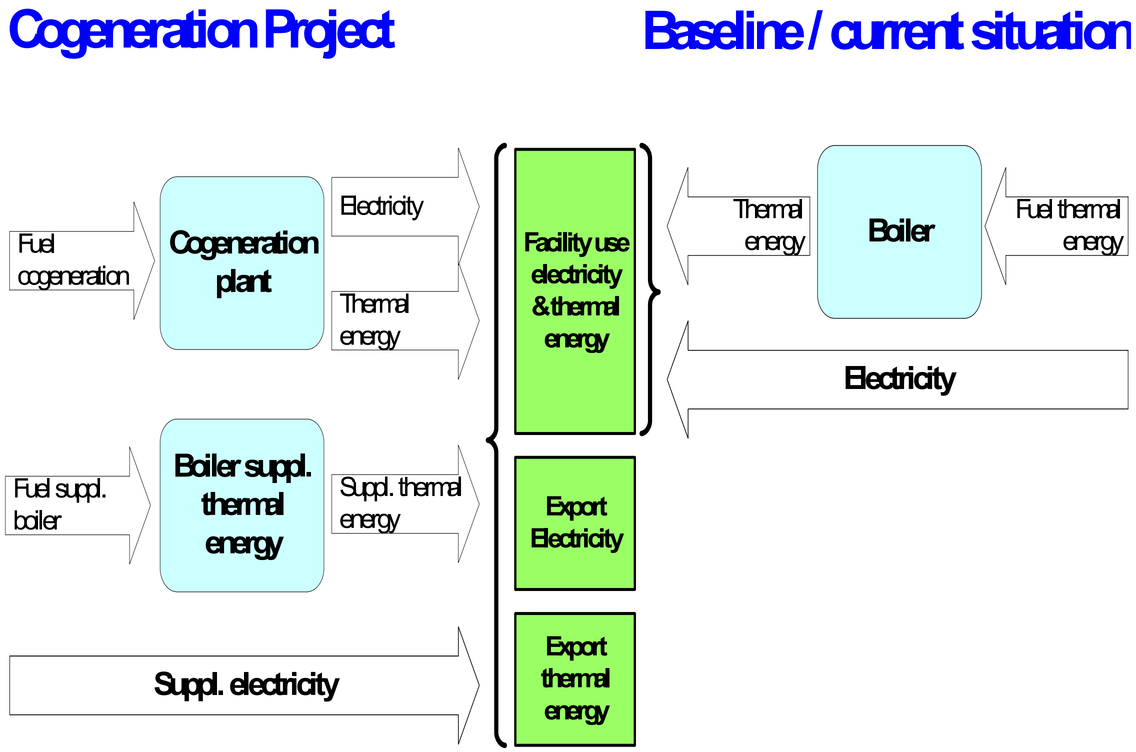

Figure 2.3: TFA model principal

In baseline or current situation, the convectional energy supply is only for facility to use electricity and thermal energy. But for cogeneration project, the facility not only can use electricity and thermal energy, but also will export the electricity and thermal energy. The comparison of the convectional energy supply and cogeneration energy supply were shown clearly in Figure 2.3. It also shows the energy streams that can be modelled in the TFA model.

Calculation principle for energy streams and cost shown in Figure 2.4. Based on that principle, calculations will be done for technical and financial analysis.

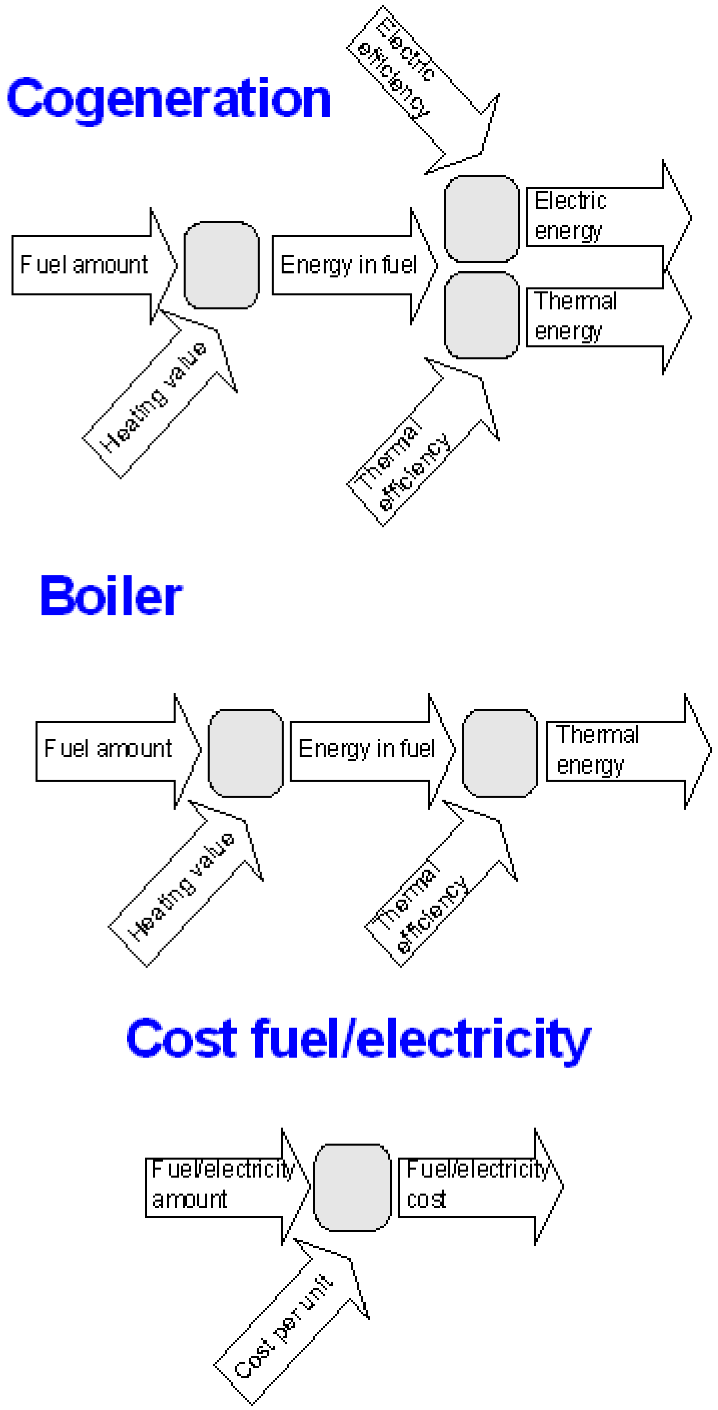

Figure 2.4: Calculation principles for energy streams and cost

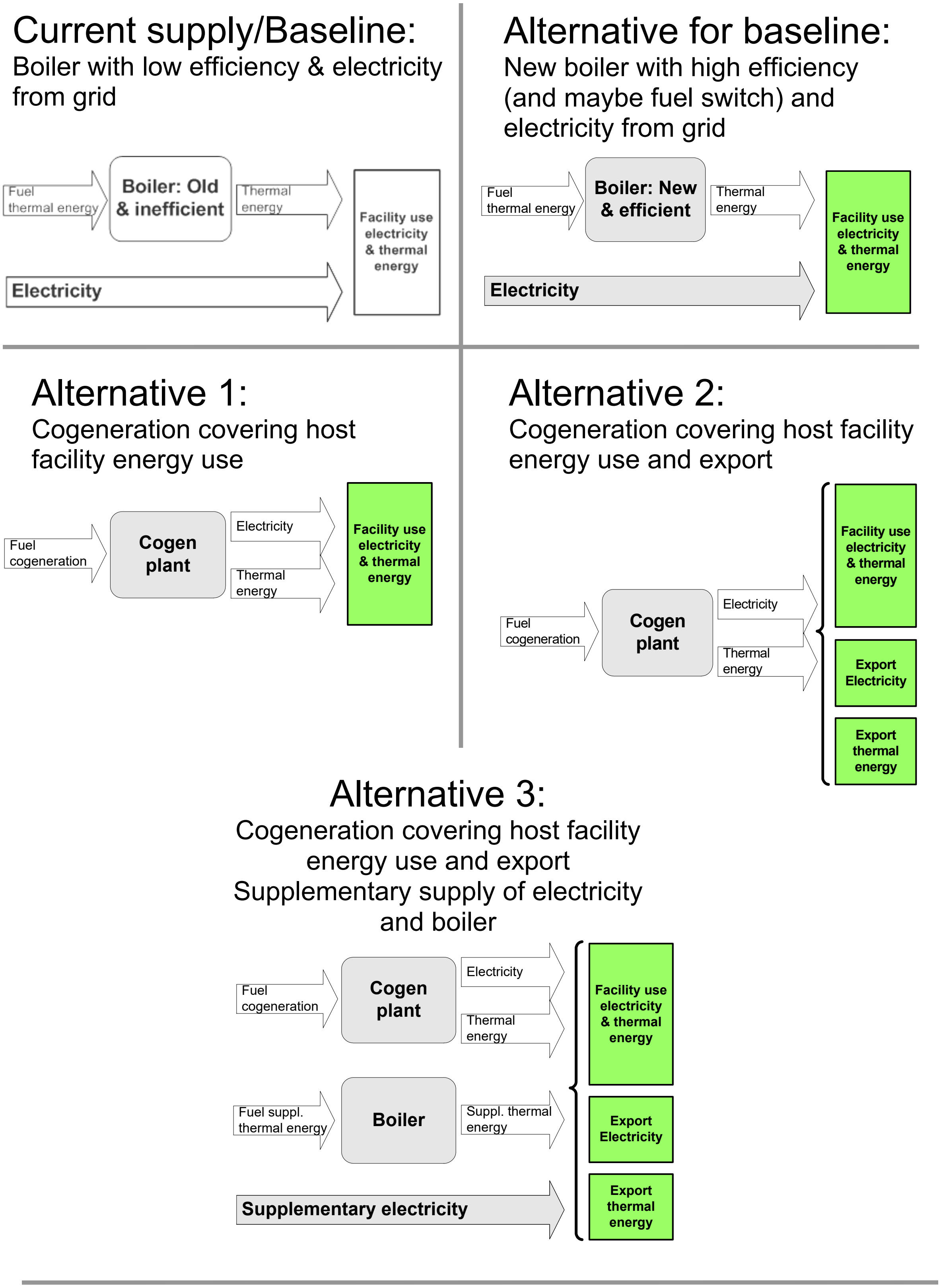

Figure 2.5: Basic alternatives of energy supply with cogeneration plant

For current energy supply situation, the existing boiler is with low efficiency and electricity from grid. For baseline, it has only one alternative. The alternative is using a new boiler with high efficiency and electricity still from grid. For cogeneration plant, basically there are three alternatives. The first alternative is cogeneration covering host facility energy use. The second alternative is cogeneration covering partially host facility energy use and supplementary energy supply. The third alternative is cogeneration covering host facility energy use and export. All this alternatives of energy supply with cogeneration plant compared with baseline is shown in Figure 2.5.This systematic approach needed to find optimal solution.

TFA has its limitations and assumptions. The limitations are for detailed design due to modelling of energy streams and cash flows on yearly basis and black box approach to cogeneration systems. The assumptions made are generation of electricity and steam/hot water correspond with requirements in facility and export obligations, energy streams and unit costs constant in lifetime, and all investments are in construction period.[2]

Here are some examples of case studies that available in COGEN 3 software.

Case 1: 1.5 MW_e Rice husk Fired Cogeneration Project.

Project type: Rice husk fuelled energy plant.
Location : Parit Buntar, Perak, Malaysia.
Description : high pressure steam from boiler is led into extraction condensing turbo-generator system, to generate between 700 to 1500 kW_e of electricity and low pressure steam for process demand. Rice husk from own rice mill is used as fuel. High quality ash is produced as by-product.
Project cost : EURO 1.714 million.

Case 2: 2.65 MW_e Bagasse Fired Cogeneration Project.

Project type: Bagasse fuelled energy plant.
Location : Phu Khieu, Chaiyapoom, Thailand.

Description : Phu Khieu Bio-energy, a special purpose company, owns a 65 MW cogeneration project consisting of 41 MW new equipment and 24 MW existing equipment from the sugar mill. The plant is a state-of-the-art high pressure system implemented to supply power and steam to the adjacent sugar mill, which in turn will supply bagasse as fuel.

Project cost : THB 2.175 million.

At current assumption rates, Malaysia's primary indigenous energy resources, oil and natural gas, are expected to be depleted soon and the country may potentially become an oil importer by the 2008. To reduce overall dependence on convectional sources of energy, the government has formulated policies and programs to encourage and stimulate the development of other energy resources, particularly renewable energy (RE). [5]

Malaysia is the world's largest producer and exporter of palm oil. Currently, 60 % or 3.5 million hectares of the country's cultivated land are under oil palm cultivation. In 2001, 360 palm oil mills processed 63 million tonnes of fresh fruit bunch (FFB) producing 11.8 million tonnes of crude palm oil (CPO), resulting in the following solid waste residues:

- 14 million tonnes of empty fruit bunch (EFB),
- 8.5 million tonnes of mesocarp fibre,
- 4.3 million tonnes of palm shell.

Only CPO is sold as a primary commodity. Most palm oil mills burn all of their fibre and some shells as boiler fuel to produce steam for CPO extraction and electricity for internal use. While some mills may have excess power to service their immediate communities, none produces enough electricity to feed into the grid.

On the other hand, while EFB can be used as soil conditioner in some estates and plantations, mulching and composting are time-consuming and non-revenue generating expenses which most millers are unwilling to undertake. Consequently, a disproportionately large quantity of EFB produced by the palm oil industry is unused. The most common practices of disposing of unwanted EFB are burning in simple incinerators, burning in the open, put in landfills, or left to rot in massive piles, all of which pose environmental problems. [6]

CHAPTER 3: METHODOLOGY

The COGEN 3 Technical and Financial Analysis (TFA) model, version 2 has:

- Calculation model for technical, financial and environmental analysis of cogeneration projects.
- Simple database for guidance, as shown in appendix A.
- Implemented in Microsoft Excel standard spreadsheet and has a transparent and open model structure.
- Developed by COGEN 3.

The TFA model is intended for pre-evaluation of cogeneration projects and is implemented in Microsoft Excel spreadsheet. The TFA can calculate the financial performance of a cogeneration project compared to electricity purchase and thermal energy (steam/hot water) generation in boiler in the host facility. A calculation of Green House Gas (GHG) emission reduction can also be done. Energy steams in the TFA model are modelled on a yearly basis to create input for financial and GHG calculations. The calculation principles ensure consistent energy input data. The cogeneration plant's generation of electricity can be supplemented with electricity purchase from grid and other sources, and the plant's generation of thermal energy can be supplemented with thermal energy generation in a supplementary boiler.

The TFA model can be used in three modes:

1. Model for financial calculations (...Yearly amount/...Lump sum). Data inputs are yearly cash flows.
2. Model for energy stream calculations and financial calculation (...Facilitation). Data inputs are amounts of electricity and thermal energy needed, type and size of cogeneration plant, investment details and the others. Using the facilitation will ensure consistency in the energy streams and generate coherent cash flows for the financial calculations.
3. Combination of (1) and (2). The selection can be done separately on section level for each cost and revenue item.

In general, the model calculates the performance of the cogeneration project compared to the current energy supply / baseline for similar energy services. This means that the requirement for thermal energy and electric energy should in baseline situation as in the cogeneration project. For the cogeneration project only export of electricity and thermal energy can be added.

For financial calculations, inputs are given in currency chosen by the user. All calculations in the worksheets will results in chosen currency as well. Straight line depreciation policy is used. Construction period is two years from contract signing to commercial operation date. Cogeneration project lifetime is assumed to be the financial lifetime of the project. The scrap value is assumed to be zero at the end of the financial lifetime. No escalation is used during the two year construction and first year of operation. This assumes that all prices should be for first year of operation (and not today's prices).

The projected cash flow of the project is the main basis for the analysis of the life cycle performance of the project. If financing is made on a project finance basis, the banks will look into the cash flow as the main source of debt service for the loans extended to the project.

The Internal Rate of Return (IRR) is the expected rate of return of the investment into the project or business. The IRR is the discount rate when the net of the present values of all items in the cash flow is zero. The IRR is calculated from the net cash flow in the cash flow table using the following formula:

$$0 = CF_0 + \frac{CF_1}{(1+IRR)} + \frac{CF_2}{(1+IRR)^2} + \ldots + \frac{CF_n}{(1+IRR)^n}$$

Where CF = net cash flow at different periods, and n = end of any period.
The decision rule to apply when using the IRR method is to undertake the investment if the IRR exceeds the company's cost of capital.

Another measurement of the viability of the investment that will be calculated is the Net Present Value (NPV). The NPV of a project is the difference between what the project costs and the value it has created due to the investment made. It is determined by computing the present value of all relevant cash flows using the formula:

$$NPV = CF_0 + \frac{CF_1}{(1+r)} + \frac{CF_2}{(1+r)^2} + \ldots + \frac{CF_n}{(1+r)^n}$$

Where CF = net cash flow at different periods, n = end of any period, and r = cost of capital or discount rate.

The decision rule to apply when using the NPV method is to undertake the investment when the NPV positive. This means that the project has created more value compared to the investment made.

The simple payback time, which is the length of time required for a project to return its investment through the cash flow it generates, is also calculated. Although this method does not reflect the time value of money and in some instances could create a misleading impression of the performance of an investment, there may be a situation in which the simple payback time could provide a useful rapid screening of the projects to a prospective investor. The discounted payback is the length of time required for a project to return its investment through the cash flow it generates, reflecting the time value of money. [4]

Sungei Dingin Palm Oil Mill (Malaysia).

Input data (Refer Appendix A):

For cogeneration project (technical),

Steam amount = 8.5 Ton/hour

= 8.5 × 7300

= 62 050 Ton

Operating time = 20 hours × 365 days = 7300 hours

Pressure = 3 bar

Temperature = 140 °C

Saturation temperature = 133.5 °C

Enthalpy = 0.7315 MWh/Ton (Refer Appendix C)

Steam turbine and boiler: 1 – 10 MW_{el} High efficiency

Gross electricity capacity = 2 MW_{el}

Parasitic load (electricity used for blowers, pumps, and so on) = 10 %

Electricity efficiency = 15 %

Thermal efficiency (possible utilization) = 65 % (Refer Appendix C)

Palm oil fibre and shell: Boiler (Wet, 45 % moisture)

Heating value (lower) = 12.55 GJ/Ton

For cogeneration project (financial),

Engineering, procurement and construction (EPC) costs = RM 35 000 000

Other investment costs = RM 5 000 000

Financial project lifetime = 20 years

Cogeneration other operating costs = RM 2 074 000

For baseline / current situation (technical),

Electricity purchase from average grid electricity Malaysia.
Electricity purchase = Electricity use in cogeneration project = 13 140 MWh
Electricity purchase rate= RM 0.198 per kWh [7] (Refer Appendix B)
Pressure for thermal energy generation = 3 bar
Temperature = 140 °C
Operating time = 7300 hours
Saturation temperature = 133.5 °C
Enthalpy = 0.7315 MWh/Ton
Boiler biomass/coal: < 10 MW_{th} Average efficiency
Thermal efficiency = 60 % (Refer Appendix C)
Diesel oil: Boiler
Heating value (lower) = 43.33 GJ/Ton
Price per fuel unit = RM 0.83 per litre
= RM 131.96 per barrel
= RM 970.29 per Ton

For baseline / current situation (financial),

Operating and maintenance cost = RM 2 890 800

Calculated / Output:

For cogeneration project (technical),

$$\text{Electricity use} = 1.8\ \text{MW}_{el} \times 20\ \text{hours/day} \times 365\ \text{days}$$
$$= 13\ 140\ \text{MWh}$$

$$\text{Thermal energy use} = \text{steam amount} \times \text{enthalpy}$$
$$= 62\ 050 \times 0.7315$$
$$= 45\ 389\ \text{MWh}$$

Gross electricity generation = 2 $\text{MW}_{\text{el}} \times 7300$ hours = 14 600 MWh

Net electricity generation = 14 600 MW $\times \left(\frac{100 - 10}{100}\right)$ = 13 140 MWh

$$\text{Thermal energy generation} = \left(\frac{\text{gross electricity generation}}{\text{electricity efficiency}}\right) \times \text{thermal efficiency}$$

$$= \left(\frac{14\,600}{0.15}\right) \times 65\,\%$$

= 63 267 MWh

$$\text{Thermal capacity} = \frac{\text{thermal energy generation}}{\text{operating time}} = \frac{63\,267}{7300} = 8.67\ \text{MW}_{\text{th}}$$

$$\text{Energy input needed} = \frac{\text{gross electricity generation}}{\text{electricity efficiency}} = \frac{14\,600}{0.15} = 97\,333\ \text{MWh}$$

$$\text{Amount used} = \frac{97\,333\ \text{MWh} \times 3\,600\text{s}}{12.55\ \text{GJ/Ton} \times 1000} = 27\,920\ \text{Ton}$$

$$\text{Energy contents} = \frac{27\,920\ \text{Ton} \times 1000 \times 12.55\ \text{GJ/Ton}}{3\,600\text{s}} = 97\,332\ \text{MWh}$$

Energy in fuel = energy contents (total) = 97 332 MWh

Adjustment of fuel input = energy in fuel – energy input needed

= 97 332 – 97 333

= -1 MWh

Need for supplementary electricity = electricity utilized and exported – net electricity generation

= 13 140 – 13 140

= 0 (It means 100 % of electricity used)

Need of supplementary thermal energy = thermal energy used and exported – thermal energy generated

= 45 389 – 63 267

= -17 878 MWh (< 0, so supplementary thermal energy not needed)

Since, thermal energy used and exported < thermal energy generated, thermal energy 100% utilized.

For cogeneration project (financial),

Construction period insurance of EPC costs = 1.5 % × EPC costs
= 0.015 × RM 35 000 000
= RM 525 000
Subtotal of other investment costs = RM 5 000 000 + RM 525 000
= RM 5 525 000
Total investment costs = RM 35 000 000 + RM 525 000
= RM 40 525 000
Contingency = 5 % × total investment costs
= 0.05 × RM 40 525 000
= RM 2 026 000
Total investment costs (including contingency) = RM 40 525 000 + RM 2 026 000
= RM 42 551 000
Equity = 100 % × Total investment costs (including contingency)
= RM 42 551 000
Cogeneration insurance costs = 0.5 % × EPC costs
= 0.005 × RM 35 000 000
= RM 175 000
Total operating and maintenance costs = Cogeneration insurance costs + Cogeneration other operating cost
= RM 175 000 + RM 2 074 000
= RM 2 249 000

For baseline / current situation (technical),

Subtotal electricity purchase cost = electricity purchase × electricity purchase rate
= $13\ 140 \times 10^3 \times 0.198$
= RM 2 602 000

(Electricity purchase from grid – electricity purchase from grid and other sources) less than 10 MWh, so electricity purchase is sufficient.

Thermal capacity = $\frac{\text{thermal energy generation}}{\text{operating time}} = \frac{45\,389}{7300}$ = 6.22 MW_{th}

Energy input needed = $\frac{\text{thermal energy generation}}{\text{thermal efficiency}}$

$= \frac{45\,389}{0.6}$

= 75 648 MWh

Amount of fuel use = $\frac{\text{energy input needed} \times 3600\text{s}}{1000 \times \text{heating value}}$

$= \frac{75\,648\ \text{MWh} \times 3600\text{s}}{1000 \times 43.33\ \text{GJ/Ton}}$

= 6 285 Ton

Energy content = $\frac{\text{amount fuel use} \times \text{heating value} \times 1000}{3600\text{s}}$

$= \frac{6\,285\ \text{Ton} \times 43.33\ \text{GJ/Ton} \times 1000}{3600\text{s}}$

= 75 647 MWh

Fuel cost = $\frac{\text{price per fuel unit} \times \text{amount of fuel use}}{1000}$

$= \frac{970.29 \times 6\,285}{1000}$

= RM 6 098 000

Adjustment of fuel input baseline = Energy in fuel – energy input needed

= 75 647 – 75 648

= -1 MWh

Rice Husk Cogeneration Power Plant (Thailand).

Input data:

For cogeneration project (technical),

Steam amount = 8.3 Ton/hour

= 8.3 × 5000

= 41 500 Ton

Operating time = 5000 hours

Pressure = 2 bar

Temperature = 120 °C

Saturation temperature = 120.2 °C

Enthalpy = 0.7226 MWh/Ton

Steam turbine and boiler: 1 – 10 $\mathrm{MW_{el}}$ High efficiency

Gross electricity capacity = 3 $\mathrm{MW_{el}}$

Parasitic load (electricity used for blowers, pumps, and so on) = 10 %

Electricity efficiency = 15 %

Thermal efficiency (possible utilization) = 65 %

Rice husk: Boiler (Dry, 12 % moisture)

Heating value (lower) = 13 GJ/Ton

Rice husk price (transport and handling) = 1000 Baht/Ton = RM 99.20 per Ton

For cogeneration project (financial),

Cogeneration equipment cost per $\mathrm{MW_{el}}$ = 15 120 000 Baht per $\mathrm{MW_{el}}$

= RM 1 500 000 per $\mathrm{MW_{el}}$

Financial project lifetime = 20 years