VIABILITY ANALYSIS OF RICE HUSK POWER PLANT FOR RICE MILLER

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ความเหมาะสมในการติดตั้งเครื่องกำเนิดไฟฟ้าจากแกลบในโรงสีข้าว

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พัคคเชษฐ์ บุญญฤทธิ์ : ความเหมาะสมในการติดตั้งเครื่องกำเนิดไฟฟ้าจากแกลบในโรงสีข้าว (VIABILITY ANALYSIS OF RICE HUSK POWER PLANT FOR RICE MILLER) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ปารเมศ ชุติมาดร., 59 หน้า.

จากสถานการณ์ที่มีแนวโน้มการขยายตัวทางเศรษฐกิจจะเติบโตอย่างต่อเนื่อง ซึ่งมีผลทำให้ความต้องการของไฟฟ้าเพิ่มขึ้นตามมา นอกจากนี้ผลกระทบจากปริมาณอุปสงค์ที่เพิ่มสูงขึ้น นี้เป็นที่คาดการณ์ได้ว่าจะส่งผลทำให้ค่าไฟฟ้าเพิ่มขึ้นตามไปด้วย เพื่อที่จะขยายการผลิตไฟฟ้าในประเทศให้เพียงพอแก่ความต้องการ รัฐบาลจึงมีนโยบายที่จะแสวงหา กำลังการผลิตไฟฟ้าจากเอกชน หรือ ผู้ผลิตรายย่อยเพื่อลดภาระการลงทุนของภาครัฐ ตามแผนพัฒนากำลังผลิตไฟฟ้า ซึ่งเชื้อเพลิงชีวมวล เช่น แกลบ ถือว่าเป็นทางเลือกหนึ่งที่อยู่ในนโยบายของรัฐบาลที่สนับสนุนการใช้พลังงานทางเลือก อีกทั้งโรงสีข้าวจะมีแกลบที่ได้จากการสีข้าวเหลือออกมาเป็นจำนวนมาก ซึ่งสามารถเอาใช้ในการผลิตเป็นพลังงานได้ ดังนั้นวิทยานิพนธ์นี้จะมุ่งประเด็นมาที่การวิเคราะห์ในการเลือกเครื่องจักรและอุปกรณ์ที่เหมาะสมสำหรับ เครื่องกำเนิดไฟฟ้าแบบชีวมวล สำหรับบริษัทกรณีศึกษา ที่จะสนใจในการลดต้นทุนการผลิต โดยใช้แกลบ ระบบที่สามารถผลิตไฟฟ้าจากชีวมวลที่จะนำมาวิเคราะห์ในบทความนี้ มี 2 ระบบ คือ ระบบผลิตไฟฟ้าที่ กระบวนการแปรสภาพเป็นแก๊ส (Gasification) และ ระบบที่ใช้กันโดยทั่วไปคือ ใช้การเผาไหม้ชีวมวลให้เกิดความร้อนแล้วนำไปผลิตไอน้ำเพื่อหมุนเทอร์ไบน์ เพื่อผลิตไฟฟ้า เพื่อประเมินความคุ้มค่าของการดำเนินงานดังกล่าว จะดำเนินการด้วยวิธีการประเมินต้นทุนตลอดวัฏจักรชีวิต (Life Cycle Cost: LCC) ซึ่งจะประกอบด้วยต้นทุนการลงทุนเริ่มต้น ต้นทุนการบำรุงรักษา มูลค่าซาก และ ต้นทุนทางสังคม โดยจะนำต้นทุนทั้งหมดเหล่านี้ มาเทียบกัน ซึ่งปรากฏว่า ในการผลิตกระแสไฟฟ้าที่ขนาด 500 KW ระบบผลิตไฟฟ้าที่ กระบวนการแปรสภาพเป็นแก๊ส (Gasification) มีต้นทุนดังกล่าวต่ำที่สุด

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต	....
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As Thailand's economic has steadily growth, it also brings an increase in electricity demand. Furthermore, the increasing of demand, it could be foreseen that the cost of electricity would also increase. To sufficiency increase the domestic power generation, government has a policy to shift the power generator to private companies or other minor companies to reduce cost of investment by government. Rice miller has produced husk by product of milling rice which could be used as biomass fuel for electricity generation. This thesis aim to present a method of how to select the appropriate machine and equipment for biomass power generator. In this case study, the systems taken into consideration are gasification and general system that use biomass fuel to generate steam for moving the turbine. Project evaluation consist of determine Life Cycle Cost (LCC) through capital recovery and operating/maintenance cost, salvage value and social cost. These two different systems were taken for comparison. The result of LCC evaluation shows that in case of the power generator scale 500 KW, gasification system has least life cycle cost.

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CONTENTS

Page

Page

Page

FIGURE CONTENS

TABLE CONTENTS

Chapter1 Introduction

To understand an overview of the research, this chapter is containing background of the Case Study Company, objective, scopes, methodology and expected benefit.

1.1 Company Background

The case study company is a Thai company ran by a family, established in 1980. At first, company has a business on rice miller on the outskirt of Bangkok. Their business is to purchase the rice grain from nearby farmland and from some other provinces around Bangkok, i.e. Nakhon Nayok, Saraburi then do the process of oven, milling, selecting and selling the white rice to exporters. The business at that time was good and ran well. However, the city growth causing the community to spread around the rice miller area which used to be located on agriculture zone that set by Department of Public Works and Town and Country Planning. Due to overflow of population, new communities around the rice miller plant start to grow converted the area to become a residential zone. This is the main reason that forces the rice miller plant to be shut down by law and regulation to prevent environmental problem, such as dust and waste water.

During that time the case study company had limited budget to move the rice miler plant to other location. Thus, in the year of 1988, Case Study Company decided to close their rice miller plant and open a manufacturer of the rice oven machine. They sell their product to other rice millers after that till now. According to that government has the policy to support the farmer by promising price of grain, the company has foreseen an opportunity to gain benefit from re-enter the rice millers industry once again.

1.2 Overview

The increasing of population and the economic that growth year by year, these two are the main drivers that cause the growth of electricity consumption of a country. The developments of renewable energy as substitute fuel for power plant are of interest in various developing countries especially to the country that import huge amount of fossil fuel like Thailand. Ministry of Energy, Thailand, has announced the policy to use renewable energy as a substitute for fossil fuel at least 25% within 10 years. They plan to attract more opportunity for the private to enter in electricity generation business especially in the renewable energy power plant. The renewable energy is an energy that comes from natural resource such as wind, sunlight, tide, geo thermal, and biomass or fuel that comes from plants based material.

The case study company currently plans to manage rice husk that come by product during the rice production processes. They normally, plan to using it as fuel for boiler in parboiled process and selling the rest that left unused to any interested. The rice husk is a waste product of the rice hullers that separate the husks as chaff from the rice which is could be used as a fuel to generate electricity in biomass power plant. Approximately 23% of the total weight of the rice being processed would result in form of the husk. The case study company, at first has a plan to open rice miller that has capacity to produce 600 tons of grain rice into rice per day. Therefore in this case 138 tons of rice husks would be available to be utilised.

In order to review the basic concept of the rice husk biomass power plant, illustrating in Figure 1-1 is the overall flow chart of the process indicating the major stages and relevant descriptions, where the rice husk is identified as an input raw material together with the electricity with the identification of the output of the process.

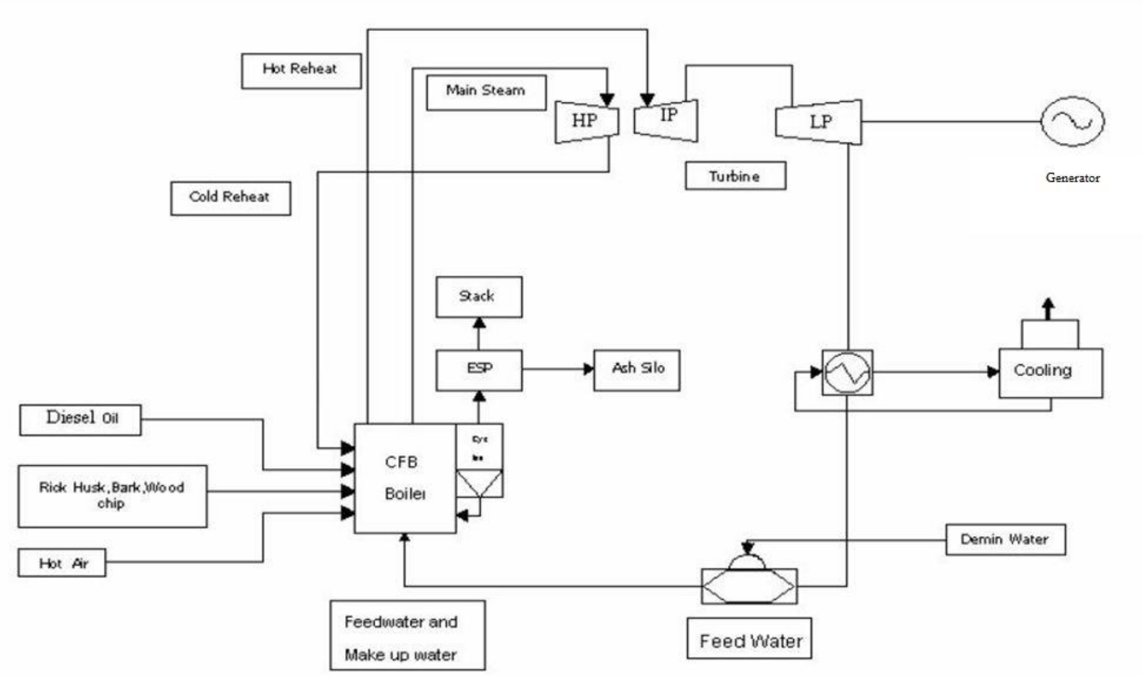

Figure 1-1 Process Flow Chart of Biomass Power Plant

Notations in Figure 1-1 can be explained as follows:

CFB: Circulating Fluidised Bed
Demin: demineralised
ESP: electrostatic precipitator
HP: High pressure
IP: intermediate pressure
LP: low pressure

The structure of power plant could be separated into 4 major parts.

1. Furnace: In other words, the combustion room the fuel or rice husks will be mix with hot air, diesel oil, wood chip and burn to generate heat in this part

2. Boiler: Receive heat energy from furnace to boil the water to generate steam

3. Water system: Function as an energy transmitter between each part

4. Turbine: Used the energy from steam to move the turbine and generate electricity

According to expert of biomass power plant, there needs to be at least 110 tons of overall fuel each day to operate the biomass power plant with a size of 4 Megawatt. While the cases study company's rice miller generate 138 tons of rice husks a day. It is possible to support the demand of biomass power plant to keep operating in each day up to the size of 4 Megawatt.

1.3 Statement of problem

As energy costs rise, so does the burden of these costs upon each company. As with virtually all other goods, the price of electricity has risen over the years. Underlying factors affecting this upward trend include higher prices for generating fuel (e.g. coal), the need for new infrastructure, and environmental concerns. Compared to other goods, the increase in electricity prices has been relatively low. More recently, this trend has reversed, due largely to poor economic conditions. However, it is expected that once the economy recovers, electricity demand and prices will once again climb sharply. To encounter this trend, the case study company could reduce the price of their electricity bill by adopting a rice husk power plant to generate electricity for the factory.

The evaluation of life cycle cost of rice husk power plant in this research is to identify if this project is suitable for the case study company to reduce cost of electricity consumption. As state in the section of the introduction, the case study company has potential and availability of fuel to use rice husk power plant up to the size of 4 Megawatt. However, the case study company has currently managing the rice husk as fuel in parboiled rice processing and sell left over to other who interested. Therefore, the statement of problem for this thesis is to set up in order to conduct the analysis to identify the appropriate system for rice husk power generator of size 500 KW.

The rice husk combustion efficiency is under the influence of moisture. The moisture in the rice husk has a direct effect to the consumption rate of rice husk in the power plant. The management of the rice husk stock need to be design in order to keep them in the environment that has a protection from water.

1.4. Objective

This research is aimed to study the viability of a biomass power plant that uses waste products from rice hullers as biomass fuel to get the least life cycle cost.

1.5 Scope and assumptions

- Study on criteria of two systems
- Study relevant cost by life cycle cost evaluation
- Selection of appropriate system between gasification and boiler and turbine power generator

1.6 Methodology

- Collected requirement and constraint of Study Company A
- Study the criteria and detail of gasification and boiler and turbine power generator
- Study relevant research
- Study investment cost and detail of expenditure by apply life cycle cost evaluation
- Collected the life Cycle Cost (LCC) and select the appropriate system
- Analysis and evaluate

1.7 Expected Benefits

The research result is the decision making process to identify an opportunity to install a rice husk power plant in the case study company. Furthermore, analyse the system that has least life cycle cost for the project between turbine and boiler power generator and gasification generator on the same size. Create opportunity to sale electricity to Electricity Generator Authority of Thailand

Chapter2 Theories and Literature Review

2.1 Life cycle cost

This analysis is a tool to evaluate the total cost of ownership over the life of an asset. Normally, it will evaluated by consider the expense or whole-life cost include, planning, design, construction and acquisition, operations, maintenance, renewal and rehabilitation, depreciation and cost of finance and replacement or disposal. There are several definitions of Life cycle cost.

Harvey's life cycle define as "The life cycle cost of an item is the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of its useful life".

The principle of this analysis is to support the decision making of projects getting the best value of investment. Life cycle cost is seeks to optimise the cost of acquiring, owning and operating physical asset over their useful live by attempting to identify and quantify all the significant costs involved in that life, using the present value technique.

2.1.1. Life cycle cost procedures

Harvey has proposed the general procedures for life cycle cost analysis summarised as shown in Figure 2-1 :

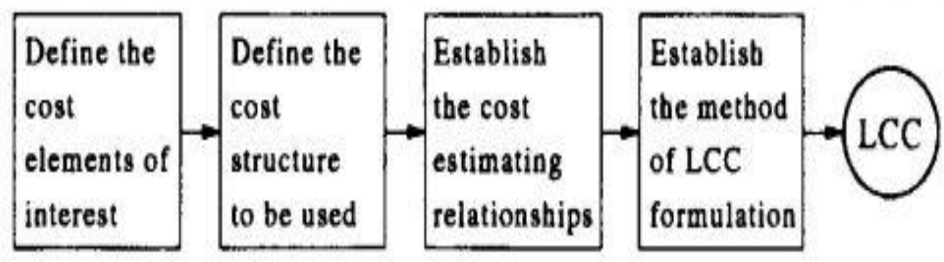

Figure 2-1Harvey's life cycle costing procedure

1. The cost elements of interest are all the cash flows that occur during the life of the asset. As define in previous sections, it agreed that the life cycle cost is included entire expenditure involved in the asset since acquisition phase to an end of its life.

2. Defining the cost structure contains grouping costs so as to identify potential trade-offs, thereby to achieve optimum life cycle cost. White and Ostward divided the costs into three categories as shown in Figure 2-2:

- Engineering and development
- Production and implementation
- Operation

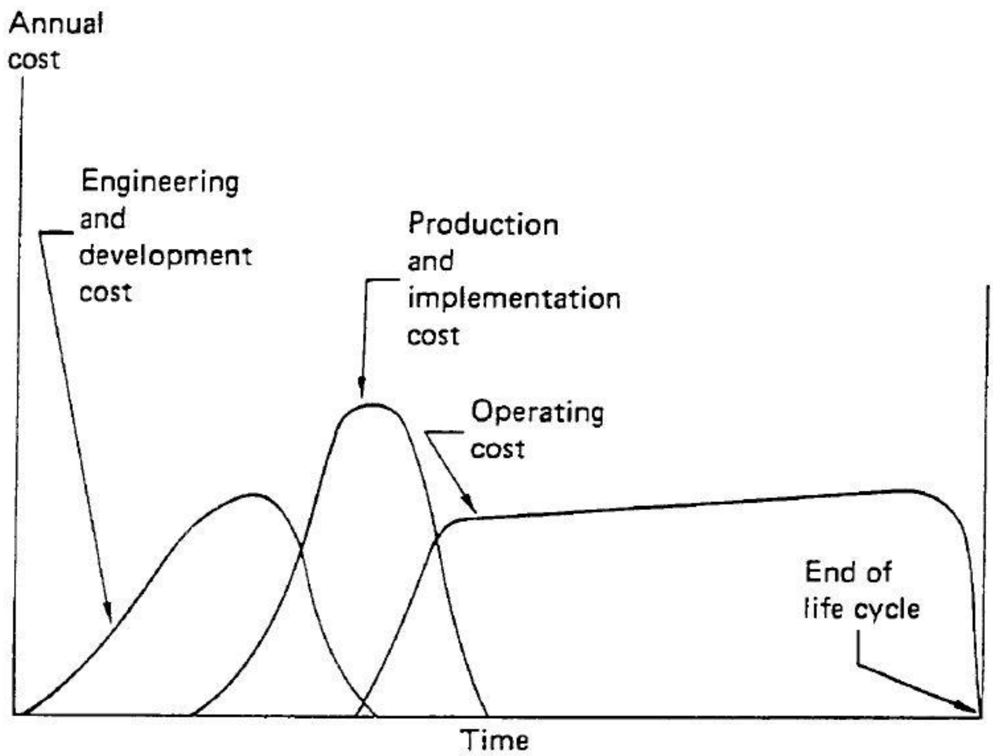

Figure 2-2 White and Ostwald's cost categorisation (stages of life cycle costs)

However, the detailed costs of each component will depend upon the nature of each particular project, system or product.

3. A cost estimating relationship is a mathematical expression that describes, for estimating purposes, the cost of an item or activity as a function of one or more independent variables. Historically-collected costs will normally be the basis of such estimates, utilising linear, parabolic, hyperbolic, etc., relationships.

4. Establishing the method of life cycle cost formulation involves selecting an appropriate methodology to evaluate the asset's life cycle cost. had provided one of the most original contributions ever to the body of life cycle cost knowledge, whereby he developed a formulation based on the eight-step approach indicated below and shown in Figure 2-3.

- Establish the operating profile
- Establish the utilisation factors
- Identify all the cost elements
- Determine the critical cost parameters
- Calculate all cost at current prices
- Escalate all costs at assumed inflation rates
- Discount all costs to the base period
- Sum discounted costs to establish the net present value

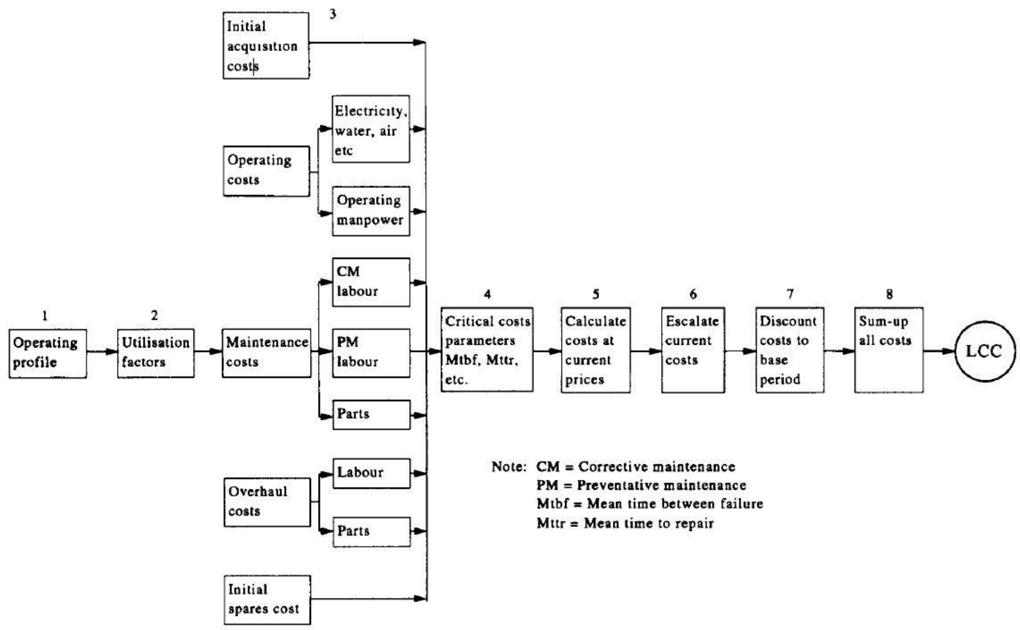

Figure 2-3Kaufman's life cycle costing formulation

2.1.2 Kaufman's life cycle costing formulation

Step 1

The operating profile (OP) describes the periodic cycle through which equipment will go, and indicates when equipment will, or alternatively will not, working. It comprises the modes of start-up, operating and shutdown.

Step 2

Whilst the previous step provided us the time schedule for operation, the utilisation factor indicate in what way equipment will be functioning within each mode of the operating profile. Thus, even within during the operation, a machine or equipment might not be working continuously.

Step 3

Every cost element or area of cost must be identified.

Step 4

The critical cost parameters are those factors which control the degree of the cost incurred during the life of the equipment.

- Time period between failures
- Time period between overhaul
- Time period of repairs
- Time period of schedule maintenance
- Energy consumption rate

Step 5

All cost are first calculate at present rate

Step 6

All costs required to be projected forward at appropriate rate of inflation. However, since this step is based on forecasted inflation rate, inaccuracy might occur. The reliability forecast could increase by assistance of expert.

Step 7

It should be recognised that money has a time value and the cash flows occurring in different time periods should be discounted back to the base period to ensure comparability.

Step 8

Summing all the cash flows involved will enable the life cycle cost of the asset to be established. Comparisons between competing assets can then be undertaken, and the fallacy of opting simply for the asset with lowest capital cost will then be exposed.

Thus, the life cycle cost could be described as formula below:

$$\text{Life cycle cost (LCC)} = C_c + C_o + S + C_s$$

C_c Capital recovery cost
C_o Operation and maintenance cost
S Salvage value
C_s Social cost

Capital recovery cost (C_c**)** is an initial investment cost of the project. We could calculate the entire cost from formula as follow, (Busaba P., 2012):

$$C_c = P[\frac{i(1+i)^n}{(1+i)^n - 1}]$$

P Present investment cost
I Interest rate per year
N Age of usage

Cost of operation and maintenance (C_o**)** is included all cost that used for operation in the entire life cycle period. It could be dividing in two categories as follows:

- Fixed operation and maintenance cost
- Variable operation and maintenance cost

Salvage value (S) is a value of salvage after the project had come to an end of its life cycle. It could calculate by follow formula:

$$A = F[\frac{i}{(1+i)^n - 1}]$$

A Actual value
I Interest rate per year
N Period

Social cost (C_s**)** is a cost arise from effect of the project to social and neighbour area. It might be pollution, environment, and disturbing the daily life of local in both direct and indirect effect. However, in this case Study Company, the size and location of power generator are not huge enough to influent to neighbour area.

2.2. Husk storage Criteria

Good storage depot is important in maintain the husk efficiency as a fuel. Rice husk is a typical dry or membranous outer covering of the rice .

1. Rice husk has high efficiency and environmental benefits. The root of efficiency could come from low boiler efficiency or high moisture content in rice husk. Thus the husk storage area should be in a place of low humidity and well protected from wind and water.

2. The low density of rice husk can cause it to be air-borne easily resulting in breathing problems, if inhaled. Thus the transportation of rice husk should be in close environment such as store in close and dry storage that protect the husk away from wind and conveyer in pipe or rail to cyclone furnace and electricity generator. Furthermore, the storage needed to be far away from labour rest area in case of health and safety issue.

2.3 Biomass power generator

Biomass is the total mass of living matter. Due to living matter on earth has carbon and hydrogen as an essence, Anything that contain these organic compounds could be used as combustion fuel. Generally, the biomass fuel would be the waste from agriculture, wood chip, remain crops after harvest and any other waste by product. It could be used as direct fuel to heat the boiler or processes before into more efficiency fuel, for instance bio diesel, cooking oil, ethanol, methane and any other synthetic gas

Nowadays, there are several valuable technologies for generating electricity power from biomass fuel. However, to achieve optimal option, it depend on several factors such as investment budget, availability, type of biomass, grain size, location, scale of power generator, humidity and any other condition of biomass. Nevertheless, in this research we would focuses on implementation on rice husk which are waste by product from rice miller processes.

2.3.1 Boiler and turbine

This system is a very basic of general power plants. It could be used with various scale of electricity production. However, if the scale is too small the price per power ratio would be high and became uneconomic.

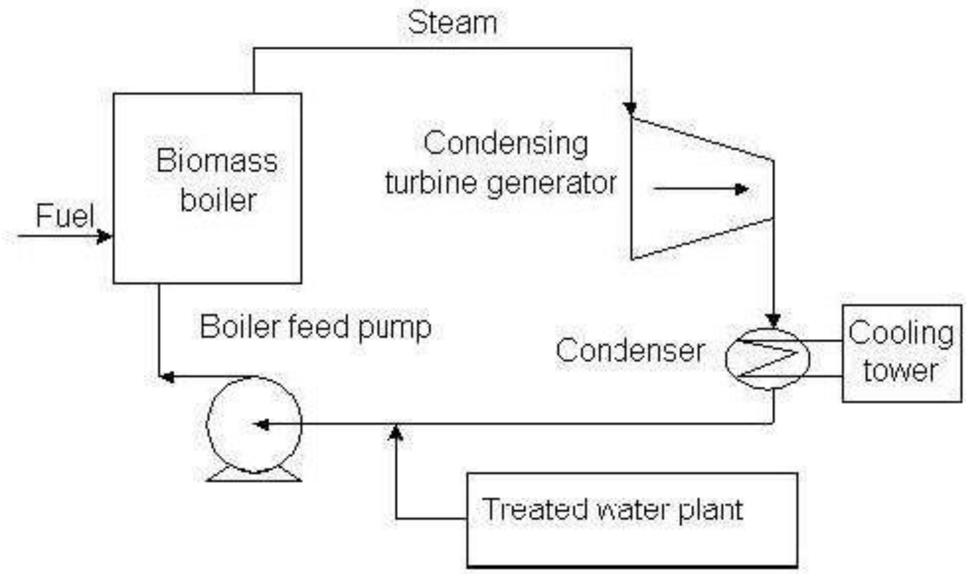

Figure 2-4 Steam and Turbine power generator

The basic concept of biomass power generator illustrate in Figure 2-4. The flow chart of the whole process was start with the input the biomass and air to combust in the furnace. The heat from this process would radiate and conduct to the lines of water tubes in boiler. The water would accumulate thermal energy to increase it temperature. The increasing temperature would rise till the boiling point and transform into high pressure steam. The steam would flow through and move the turbine to generate electrical power. The lower pressure steam that left from the turbine would flow through the condenser and cooling tower to release their thermal energy and condensed back to water. This water would flow to boiler and circulated in this system again.

The outcome of these processes would be remaining ash and electricity. The ash was consisted of high silica and could be used in many industries such as cement additive fertilization in fields and chicken incubation much more.

In power generation process, the fuel for combustion the boiler is essential if we have not enough we might need to purchase other fuel i.e. wood chipped, oil or purchasing rice husk from other mill. Although it could easily solve the problem of lacking fuel but this action need time for delivery and might lead to increase cost of production. Thus managing the husk inventory to the exact level or plan of safety stock would be required.

Normally, the turbine specification would be varied up to efficiency, durability, consistency and term of warrantee within the designate budget. In this case, the manager decided to use whole system from one contractor. It was due to trade the design job and maintenance service to single contractor for easily control. However, up on selection the biomass generator they had some criteria which required watching such as erosion from SiO_2, maintenance service and durability. The overall efficiency of this system is about 15-20% up to technology, equipment efficiency and system design.

2.3.2 Gasification

Electricity can be produced using the well-established gas turbine combined cycle technology commonly applied in refinery systems using natural gas or refinery gas. The combined cycle will be more efficient than direct combustion in a steam plant .

The principle of this process is to converts biomass fuel or any other carbon based material into synthesis gas, the mixture of carbon monoxide, hydrogen, carbon dioxide and any other complex hydrocarbon. And then utilise this synthetic gas by used as fuel for combustion engine to generated electrical power. Nevertheless, generally this process would generate tar, acid and some light ash by product. These contaminated would contain in the synthetic gas and would affect the engine by corrosion and polluted the exhausted air. As such we need to put synthetic gas into pre-treatment such as cool down the temperature and remove contaminated compound before take into use.

Use of Syngas

The syngas obtained by gasification process could be used on thermal application or for mechanical or electrical power generation as substitute of natural gas.

Thermal

1. Dryers: Drying is the most essential process in food industry such as tea and dried fruit. This calls for hot gases in the temperature range of 120 130°C, in the existing designs. Typically the heat energy required is equivalent to 1 kg of biomass for 1 kg made tea. Gasifier is an ideal solution for the above situation, where hot gas after combustion can be mixed with the right quantity of secondary air, so as to lower its temperature to the desired level for use in the existing dryers.

2. Kilns: Baking of tiles, potteries or any other product that require baking in the temperature range of 800-950°C. This is presently being done by combusting large quantities of biomass in an inefficient manner. Gasifiers could be suitable for such applications, which provide a better option of regulating the thermal environment. There will also be an added advantage of smokeless and sootless operation, whereby enhancing the product value.

3. Furnaces: In non-ferrous metallurgical and foundry industries high temperatures (~650-1000°C) are required for melting metals and alloys. Typically in the industries, the task was done by oil fuel or electrical heaters.

4. Boilers: The industries that required generating steam or hot water commonly use either biomass or coal as fuel. The biomass that used directly as fuel would easily causeNO_x and got low efficiency.

Power generation

Syngas can either take into use in mono or dual-fuel mode. In case of mono-fuel mode, the gas is directly use as fuelled to internal combustion engine. While the dual-fuel mode would take into operate along with small quantity of other liquid fuel such as gasoline. The choice of selection is varied by the economics of operation.

Chapter3 Collect the Requirements and Constrains

In this section, we will discussed about acquiring the criteria and information that concerned by shareholder of Company A.

3.1 Meeting and Shareholder constraint

We had chance to participate in the meeting with shareholder and staffs of Company A. During the discussion, the shareholder had shown his interested in project related to reducing their cost of production. They concerned about the price of electricity and minimum wage which keep increasing year by year. The automation, reliable and low maintenance is required it was due to they currently had a problem about recruited new worker. Thus, they had plan to use automation system for solve the lack of workforce problem.

They concerned that the system should run by its own to prevent a chance the miscellaneous problems which might occurred from unskilled staffs. Furthermore the plant is normally operates 24 hours for 7 days a week, therefore the reliable would be main essential to keep the production line to properly function. Moreover, due to the company A was recently established, they had financial constraint.

3.2 General information

Figure 3-1View of the case study company

The case study company (as shown in Figure 3-1) located at Angthong Province encompasses land approximately 3,000 rai. The plant normally operates by 100 workers and 10 office staffs. They manage the staffs into 2 shifts daily. Most of them are unskilled worker which had high rate of turnover.

The plant has 6 production lines for rice milling and 3 line for par boiled rice. The capacity per day is able to producing up to 600 tons of grain rice turn into rice. The processes of the rice milling is start by receive rice bran from the hopper then used the separator to remove the dirt or any other foreign object such as pebble some part of the rice plant. The pass it though the hulling machine to remove the husk after that the vacuum would collect husk and dust from the rice. The rice would come into grading machine to check the brown rice. This stage would screen the rice that still contain the husk and send them back to reprocess. After all of the rice were de-husk, the rice would flow through milling machine and whitening machine to polish the rice to be white. During the process there will be small net to remove dust, broken rice and remain husk from the production line. The remains from these processes would be white milled rice.

According to Mr Panop Suteechate (2014), director of company A, he estimated by his long experience in this business that the rice husk would be available to be utilised would be 120-130 tons per day if the plant work at its designed capacity.

Currently, their plant is using all electricity from Electricity Generating Authority of Thailand (EGAT). The rice husk which came by product is currently stock at the storage at the back side of the plant in the 10 silos.

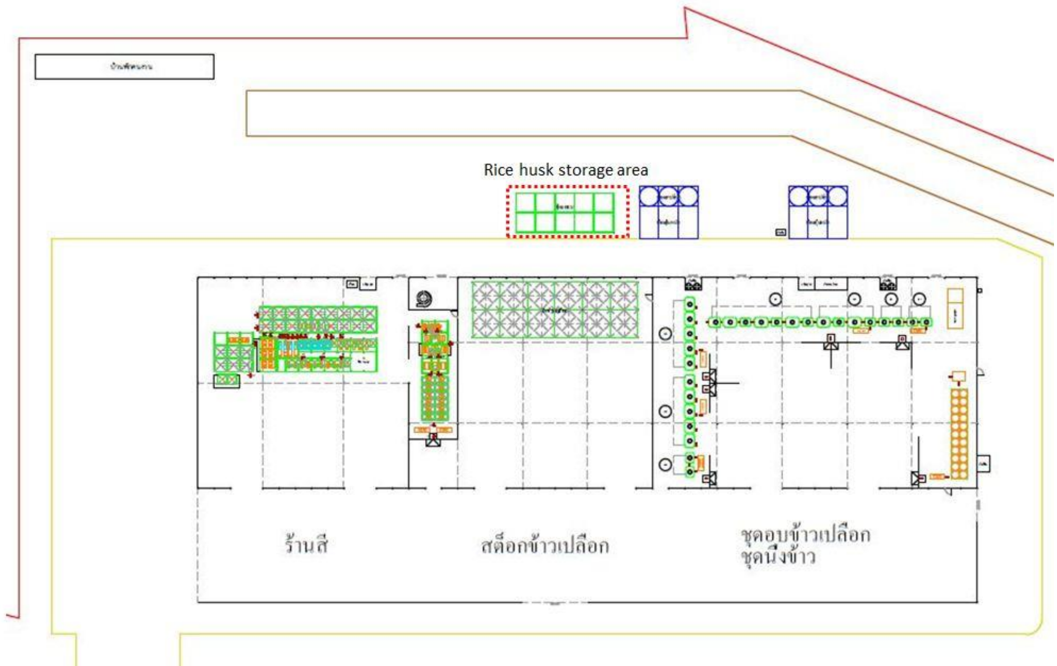

Figure 3-2Plant layout of Case Study Company

As we mentioned above, the rice husk were kept in storage silos located at the rear side of plant as shown in Figure 3-2 and Figure 3-3. The company normally used them as fuel for boiler in par boiled rice production. They sell the left over to local fertiliser factory and biofuel power plant. The buyer come and bought the entire rice husk stock monthly. The loading and transportation would all perform by the buyer. The price of rice husk is varied up to season and local demand but according to Mr. Panop, they normally sold them at the price in range of Baht 1,500 – 1,800 per ton. There also has a farmer came to buy ash left from the par boil rice production. The company sold them by bulk of 25 tons at the price of Baht 1,000 or roughly Baht 0.04 per kg. The farmer would normally use them as fertiliser.

Next to rice husk storage area is empty space which had opportunity to be the designated place for install the bio mass power generator system

Figure 3-3View of rice husk storage area

After gathering required information and criteria, we then use the information to plan the conceptual design to satisfy the requirements.

3.3 Technical constraint

We had discussed about the scale of power generator with them. In this case they interest in the 500 KW biomass gasification power generators. Although they have material and free area sufficient enough for bigger size, the managers decide to select this size. It is due to their decision to test the outcome and financial restriction. Moreover, they prefer to use cyclone due to it has advantage as follows:

- Low fuel preparation on both time and cost
- More compact than any other furnace
- Less fly ash and convective pass slagging

3.4 Conveyor system

The scale of bio fuel conveyor system is selected by the Case study Company. We had review on the system used for delivered the material, rice husk, to the furnace by compare various alternative with their constraint. The detail is as follows:

1. Conveyer belt

Although, this would come with high cost of investment but it had advantage in promising with the automation concept which would reduce the staff required to operate the system along with reliable and provide sufficient rice husk to burner. It also easy to maintenance due to it currently used in carry the material around the plant. However, it has highest cost between any other alternative choices.

2. Vehicle/ worker

By utilising wheel loader or worker, it required minimum budget for start implement among other choice. However, it required numbers of staffs to achieve the system operate as design condition.

3. Pneumatic conveying

The advantage of this system is it required only one machine which is a fan for creating vacuum in order to deliver the rice husk through the pipe to the burner. However this system would came with constraint to install the burner next to the rice husk storage to reduce the corner of the pipe system as much as possible. It is due to in some case the rice husk could contain humidity and start to stick together and caused the system to choking. Although had choking problem it well suited with the cyclone burner.

4. Screw loader

It was used for carried the material in form of grain or small chipped. It normally used for feeding the machine to continuous operate. The disadvantage of this system is about the maintenance. Due to the screw is constructed by casted steel when corrosion or any breakdown occurred and at the screw, it is required to remove the whole piece to repair or replace.

3.5 Production processes of biomass power generator

Biomass is the total mass of living matter. Due to living matter on earth has carbon and hydrogen as an essence, it could be used as combustion fuel. These renewable organic materials are such as husk, wood, any other agricultural crops or municipal wastes especially when used as a source of fuel or energy. Biomass can be burned directly or processed into biofuels such as ethanol and methane.

There several technology which currently in used to convert these biomass in to electrical energy for instance boiler and steam turbine, and gasification.

3.5.1. Steam and turbine

This system is a very foundation of general power plants. It could be used with various scale of electricity production. However, if the scale is too small the price per power ratio would be high and became uneconomic.

The basic concept of biomass power generator illustrate in Figure 3-4. The flow chart of the whole process was separated by equipment into 5 stages. Start by rice husk as an input pass through each stage of equipment and result in electricity as an output.

Start with the fuel reception stage, the husk would be collected from production or any other neighbour area in case of purchase from other. Firstly the staffs would perform initial check the parameter of the husk for instance; moisture, weight etc. and then delivered them to storage

In fuel hall, the husk should keep separate by a few meters away from each another and sorting by date received for the purpose of

- First in-first out to reduce the volatile matter and fuel quality as they depreciated when time pass by.
- The moisture control
- In case of fire

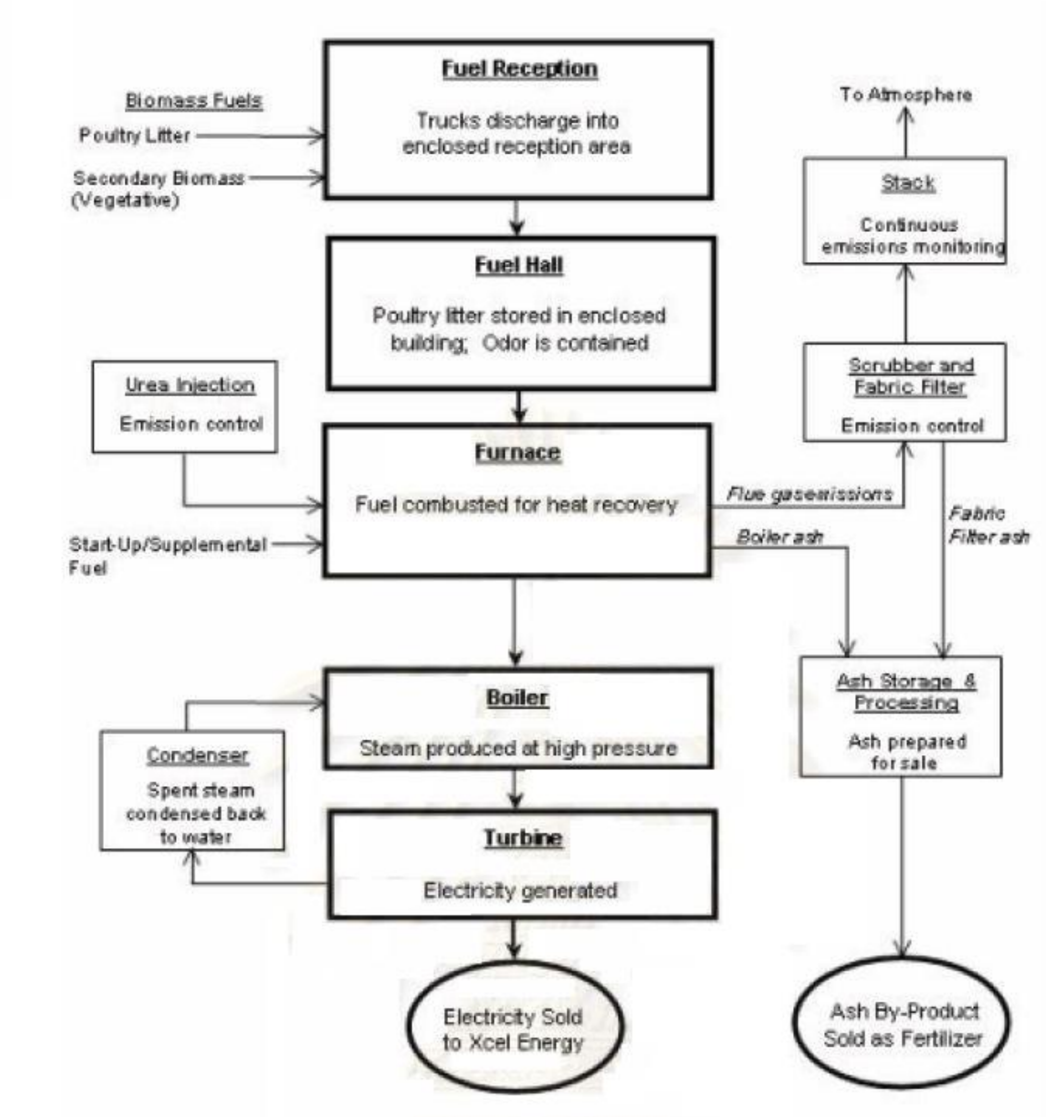

Figure 3-4Flow chart of the biomass power plant Source: Fibrominn Co., Ltd homepage.

Normally, the fuel hall should be seal from outer environment or has water and wind proof to prevent the fuel from efficiency reduction.

In the furnace stage, the processes are initiated by the pre-heating process with oil in order to increase the temperature to reach designated level at 700-800 degree Celsius. After that point the furnace could use only husk as fuel supply. A husk and pre-heated air from economiser would mix up and feed into the furnace through the burner. After combustion, high density bottom ash would be fallen and remove by cyclone furnace.

At boiler where the water fed in would be boiled up by heat from furnace to the become steam which temperature of 480 degree Celsius and 65 bars. After that the steam would move to turbine to generate the electricity. The steam left from turbine would transferred to condenser to convert them back to liquid form before being pumped through the water heater and DE aerator to fed back to boiler.

Lastly at the turbine, the turbine would convert the pressure from steam into electricity. The steam would drive the turbine and generate the electricity as the turbine move.

The outcome of these processes would be ash and electricity. The ash was consisted of high silica and could be used in many industries such as cement additive, fertilization in fields and chicken incubation.

In power generation process, the fuel for combustion the boiler is essential if we have not enough we might need to purchase other fuel i.e. wood chipped, oil or purchasing rice husk from other mill. Although it could easily solve the problem of lacking fuel but this action need time for delivery and might lead to increase cost of production. Thus managing the husk inventory to the exact level would be required.

Normally, the turbine specification would be varied up to efficiency, durability, consistency and term of warrantee within the designate budget. In this case, the manager decided to use whole system from one contractor. It was due to trade the design job and maintenance service to single contractor for easily control. However, up on selection the biomass generator they had some criteria which required watching such as erosion from SiO2, maintenance service and durability. The overall efficiency of this system is about 15-20% up to technology, equipment efficiency and system design.

3.5.2 Gasification

It is a process that converts biomass fuel or any other carbon based material into synthesis gas, the mixture of carbon monoxide, hydrogen, and some carbon dioxide and any other complex hydrocarbon. And then this synthetic gas could use for combustion engine to generated electrical power. Although, in general this process would generate tar, acid and some light ash. These contaminated the synthetic gas and would affect the engine by corrosion and polluted the exhausted air. As such we need to put synthetic gas into pre-treatment such as cool down the temperature and remove contaminated compound before put into use at combustion engine.

Typically, synthetic gas has a heating value at 4.6 MJ/m^3 which approximately 1/7 to natural gas. The heating value could increase by use pure oxygen instead of atmospheric air. However, that would come with increasing cost. Nevertheless, synthetic gas could be used as alternative fuel aside from natural gas to generate power in combustion engine (University of Suranaree).

The practical to generate synthetic gas is simple yet but in principle it contains two-stage of chemical reaction. The processes start at put roughly grain of biomass into combustion chamber from top while the combustion occurred at bottom as illustrated in Figure 3-5.

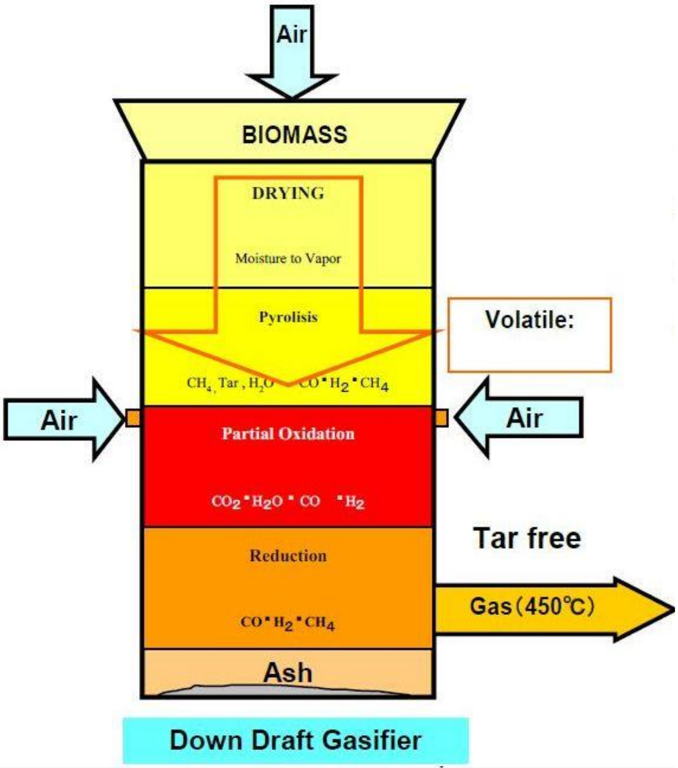

Figure 3-5Gasification process

The two stage reaction consisting of oxidation and reduction processes. Both of the processes occur under sub-stoichiometric condition of air with biomass. The affected of sub-stoichiometric is caused the oxidation to loss of volatile from biomass and is exothermic at high temperature. The process would generate various gaseous products, for instance, carbon monoxide, hydrogen, water vapour and a bit of carbon dioxide which in turn are reduced in part to carbon monoxide and hydrogen by the hot bed of charcoal generated during the process of gasification. Reduction reaction is an endothermic reaction to generate combustible products such as carbon monoxide, hydrogen, methane, as indicate on Figure 3-6.

$$C + CO_2 \longrightarrow 2CO$$
$$C + H_2O \longrightarrow CO + H_2$$
$$C + 2H_2 \longrightarrow CH_4$$

Figure 3-6 Reduction reactions in gasification process (www.cgpl.iisc.ernet.in)

Since main element to supply the reduction reaction is Carbon, in other word char left from gasification process the entire operation is self-sustaining.

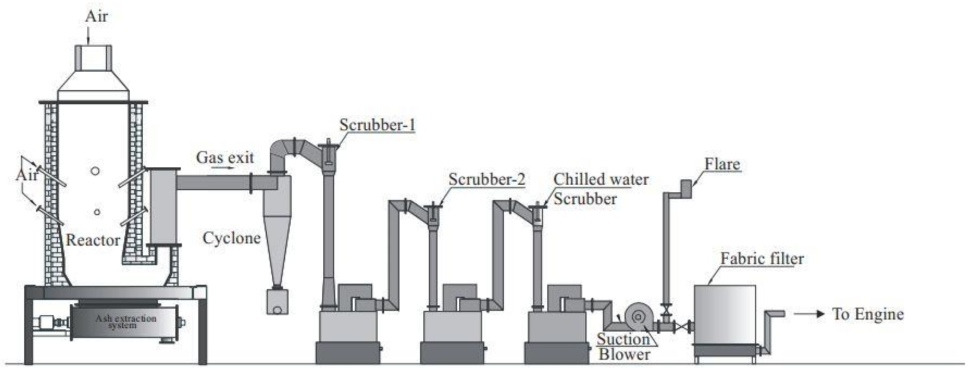

Figure 3-7typical configuration of the gasification process

At the last stage, reduction reaction, where synthetic gas runs passes through the char that caused the chemical reaction in Figure 3-6. In this stage the size of the fuel is very influence.

In case of the fuel grain size is too big, had low on ratio on outer surface area per volume. The excess oxygen would had a space to carried by fuel into the system and caused the chemical reaction became oxidation instead of reduction. This would greatly affect to the efficiency of the biofuel gas generation system.

However, in case of the fuel grain size is too small, the small grain would carry by the synthetic gas into the system and caused the system became low on pressure. This would cause us to increase the fan size to be bigger and cost higher energy consumption. The output product, synthetic gas would also contain much more dirt and smog particle.

3.6 The process of gasification generator

The whole system is as shown in Figure 3-7. The gasification power generator is normally separate into 3 main parts. The detail is as follows:

1. Gasifier

On the outside would surround by insulation to reduce the heat loss in the process. The furnace would receive fuel from hopper feeder. On the side of the furnace would have intake air pipe for control the air supply for the furnace. On the bottom of the furnace would be bottom bed for remove the ash and excess char from the system.

2. Gas treatment unit

Cyclone collector was installed to remove the ash and big particle of dirt from the synthetic gas. The process was used the centrifugal force from the vortex of synthetic circulation through the cyclone collector unit. The dirt free synthetic gas would move through the upper of the cyclone unit and pass through water scrubber and chiller scrubber.

The water scrubber is a processes installed for removal of small dirt particle from synthetic gas. The principal of the system is to let the synthetic gas flow pass through the normal temperature water spray. The water would grab the small dirt particle that flow pass by water and fall down. This process could be repeated if the synthetic gas had contained a lot of small dust and dirt.

The Chiller scrubber is used for screening tar and remaining dust. The system would be the same as water scrubber but decrease the water temperature from normal temperature lower at 10 degree Celsius. At this temperature the tar that is in the form of gas would condense and fall down together with low temperature water.

The synthetic gas that flow passes through these would contain an amount of humidity. As such, in some system the biomass filter might add to remove the humidity and remained tar from the synthetic. The addition system normally be let the synthetic gas flow through a chipped wood and flow next to fabric filter unit which would remove the small particle dust and remain humidity by using very small bag.

3. Generator

Engine Generator set would consist of Gas-Otto engine that connected with synchronous generator. The engine was design and adjustment to use the synthetic gas as fuel.

The efficiency of the gasification power generator is varied up to many factors but in general, it would be around 20-30%. The detail of factors is as follows:

- Economiser for reusing the exhaust gas
- Technology and adjustment to control the temperature in Gasifier to maximise the
- Efficient of oxidation and reduction reaction.
- Biomass fuel humidity and other condition
- Control of air and oxygen in the furnace

Efficiency of equipment and design

3.7 Life cycle cost

Refer to requirement and constraint collected from brainstorm with managing of the case study company, the calculation would base on assumption as follows:

Power generation	500	KW.hr
Operation time in a year	7,008 hours	
Average plant factor	80%	

In this research, we would compare between two systems which are gasification and boiler and turbine. The age of usage for gasification generator is up to 20 years while boiler and turbine is up to 30 years.

3.7.1 Capital cost

The capital cost is a cost related to cost of building construction, machine and equipment cost, infrastructure. The detail is as follows:

1. Building would locate on the empty space next to husk silos. It would be general factory building size 10 meters width 15 meters length. Within this size it could be able to house whether gasification generator or boiler and turbine generator.

2. The machine and equipment would be depending on the selection systems. The conveyer system to deliver husk from silos to this building would be length approximately 25 meters.

3. The cost relating to infrastructure such as electrical system and controller, construction planning, and transportation and tax for imported machine and equipment.

3.7.2 Operation and maintenance cost

The cost for maintenance and operation could divide into

1. Fixed operation and maintenance cost is consisted of

- Wage
- Spare part
- Overhead cost
- Maintenance cost

2. Variable operation and maintenance cost is consisted of

- Fuel cost
- Miscellaneous cost

3.7.3 Salvage value

The value amount that estimated to receive after sells the asset after end of its usage age.

3.7.4. Social cost

The cost arises from affection of the project cause to social and neighbour area. It might be pollution, environment, and disturbing the daily life of local. However, in this case Study Company, the size and location of power generator are not huge enough to influent to neighbour area.

Chapter4 Data Analysis

In this chapter, we would discuss in detail about the data analysis to select the optimum choice in this chapter. We will discuss about the cost of investment for the project and Payback period. The cost analysis would estimate the expenditure involved in the initial investment for construction, operation and maintenance, fuel cost and revenue generate from selling electricity back to EGAT. After we gain all required information and data, we then calculate entire outcome and income to identify the Payback period.

4.1 Machine and equipment specification

We would analyse the cost by compare between gasification power generator and boiler and turbine power generator. Both of them used the same biofuel which is husk. The different is on equipment, efficiency of the system in theory and system design. We would set condition that both systems had to produced 500 KW

4.1.1 Conveyor system

Refer to our meeting with shareholder and manager of company A which we discuss the detail in previous chapter. In summary the list of evaluated criteria for the system had to be as follows:

- Cost of investment
- Energy consumption
- Number of staff required to operate
- Cost of maintenance
- Ease to maintenance
- Durability
- Flexibility to another fuel
- Ease to clean

According to the meeting with staffs we had found that they had financial constraint due to newly open business that less than a year. As such, they reviewed various turbine specification compare to the price and discuss with manager and director.

They selected the size of biofuel power generator at 500 KW. The conveyor system required to be approximately 25 meters length from the husk storage silo to new construct building which located on empty space next to the husk silos and approximately additional 8 meters for inside building. In conclusion, they selected Pneumatic conveying to use as conveying system.

4.1.2 Boiler and Turbine

Currently, there are numerous alternative of turbine selection. However, as we discussed in previous chapter, the manager has decide the turbine and other equipment based on their financial restriction and technical issue. The specification of this case study was 500 kW a system of 4-poles synchronous generator. The boiler would be purchase by set including furnace and economiser. The specification of boiler is to generate steam at 12 ton per hour, pressure 10 bars and 7,500 kW/hr. According to supplier, the machine could operate for 30 years.

4.1.3 Gasification

Refer to the same condition as boiler and turbine generator, the specification to achieve the same productivity would be illustrated in Table 4-1.

Table 4-1Specification of 500 KW gasification generators

Description	Specification
Fuel consumption	400-800 kg/hr.
Water content	10-15%
Gasification capacity	100-1,200 m^3
Generator capacity	400-500 KW

According to supplier, the usage age of this type of generator is at 25 years.

4.2 Life cycle cost analysis

4.2.1 Capital cost

In this part we would focus on discussion about the cost of initial investment for machine and equipment, building and other infrastructure required. The turbine and boiler power generator has list of equipment as illustrated in Table 4-2:

Table 4-2Turbine and boiler power generator machine and equipment list

Item	Description
1	Boiler
2	Turbine and power generator
3	Tubing and accessories
4	Condenser
5	Electrical equipment
6	Cooling tower
7	Additional equipment
8	Controller
9	Pneumatic Conveying
10	Construction of building

The gasification power generator has list of equipment as illustrated in Table 4-3:

Table 4-3Gasification power generator machine and equipment list

Item	Description
1	Gasification generator
2	Accessories and other equipment
3	Controller
4	Pneumatic Conveying
5	Electrical equipment
6	Construction of building
7	Cyclone
8	Water chiller
9	Suction blower

Building

The cost of building construction was calculated from assumption that the machine required operation area at approximately 150 m^2 factory building. The building would contain all machine and equipment along with hopper and pneumatic conveying that supply the husk from silos. The location of the building for housing the power generator is an empty space next to husk silo. The building size that fit to house these systems is estimated to be at width 10 meters and length 15 meters. We used the middle price from OIC which indicate that the cost of construct a basic factory building would cost approximately Baht 7,610 per m^2. Additional, we apply overhead and profit to cover the construction management and building design expense. Hence, the cost of building would be as shown in Table 4-4:

Table 4-4Cost of building construction

Building	Baht 1,141,500
Overhead and Profit 10%	Baht 114,150
Total	Baht 1,255,650

However, the rate of construction cost from OIC is based on 2013. Therefore, we had to convert the cost to present by apply inflation rate. According to Bank of Thailand, the record of inflation rate of Thailand is as illustrated in Table 4-5.

Table 4-5Thailand inflation rate year 2010-2014

Year	Inflation Rate
2010	-0.90 %
2011	3.30 %
2012	3.81 %
2013	3.02 %
2014	2.18 %

The inflation rate of 2014 is at 2.18%. Hence, the cost of building construction after apply inflation rate would amount to Baht 1,283,023.17.

Machine and Equipment

The cost of machine and Equipment would separate by Boiler and Turbine Generator and Gasification generator as follows:

Pneumatic conveyor

Refer to the supplier., the case study Company's main supplier, it appearing that the cost of the whole conveying system included electrical system and controller would be at Baht 450,000. The price had included cost of installation, system testing and transportation.

Boiler and Turbine generator

The case study company had machine selection and consult with their convention supplier, City lion Co., Ltd. They acquire specification and cost for boiler and turbine generator which describe and break down and shown in Table 4-6.

Table 4-6 cost of investment for boiler and turbine generator

Table 4-6 cost of investment for boiler and turbine generator

Description	Cost
Boiler	Baht 9,000,000
Turbine and power generator	Baht 10,000,000
Tubing and accessories	Baht 800,000
Condenser	
Electrical equipment	Baht 500,000
Controller	
Cooling tower	Baht 100,000
Total	**Baht 20,400,000**

Gasification generator

We enquired the cost of gasification generator from supplier.The quotation was in set of machine and equipment included the cost of transportation and installation. The cost of the whole system consisting of Gasifier, 2 units of Cyclone Separator, 2 units of Spray scrubber, 2 units of Venturi scrubber, Spray scrubber and Spray Filter (for removing dust, tar and cooling), Alkali water washer, gas-water Separator, combustion engine and generator. The cost of investment for Gasification generator would be as shown in Table 4-7:

Table 4-7Cost of investment for Gasification Generator (Shangqiu Haiqi Machinery Equipment Co., Ltd. (2014))

Item	Description	Cost
1	Gasification generator	Baht 15,000,000
2	Cyclone	
3	Water chiller	
4	Suction blower	
5	Accessories and other equipment	Baht 400,000
6	Controller	Baht 800,000
7	Electrical equipment	Baht 500,000
	Total	**Baht 16,700,000**

Conclusion

The capital cost for each type of power generator would be as shown in Table 4-8:

Table 4-8 Summarise capital cost

Description	Gasification	Boiler and Turbine
Machine and Equipment	Baht 16,700,000.00	Baht 20,400,000.00
Building	Baht 1,283,023.17	Baht 1,283,023.17
Conveyor	Baht 450,000.00	Baht 450,000.00
Total	**Baht 18,433,023.17**	**Baht 22,133,023.17**

From table 10, we could calculate the capital recover for entire age of each power generator from formula.

$$C_c = P[\frac{i(1+i)^n}{(1+i)^n - 1}]$$

P Present investment cost
I Interest rate per year, typically use 12%
N Age of usage

The usage age of gasification power generator is 25 years while boiler and turbine power generator is 30 years. Hence the capital recovery is as follows:

Gasification power generator Baht 2,350,210.45
Boiler and turbine power generator Baht 2,744,494.87

Cost per unit for each type of generator would be calculated by based on assumption below:

Power generation	500	KW.hr
Operation time in a year	7,008	hours
Average plant factor	80%	

The result is as follows:

Gasification power generator	0.0335 Baht/KW.hr
Boiler and turbine power generator	0.0326 Baht/KW.hr

4.2.2 Operation and maintenance cost

The cost for maintenance and operation could divide into

1. Fixed operation and maintenance cost is consisted of

Wage
Spare part
Overhead cost
Maintenance cost

2. Variable operation and maintenance cost is consisted of

Fuel cost
Miscellaneous cost

Fixed operation and maintenance cost

According to EGAT , they estimated the maintenance cost for machine and equipment typically would be approximately 1.5% of investment cost. The depreciation calculated by usage age of power generator which is 25 years for gasification power generator and 30 years for boiler and turbine power generator.

Variable operation and maintenance cost

The fuel consumption would calculated by average cost of rice husk against the consumption for entire year for operate the generator. The calculation would base on assumption that the biofuel power generator has operated 24 hours for 365 days a year which equal to 8,760 hours of electricity production. However, we expected it to produce electricity at 80% of this operating hour. Hence, the operating hour would amount to 7,008 hours a year.

We enquire the husk price from Energy for environment foundation. The data of year 2014 is collected and shown price Baht per ton as illustrated on Table 4-9:

Table 4-9 Rice Husk price

Month	Kumphaeng Phet	Suphan Buri
Jan	Baht 1,000	Baht 1,100
Feb	Baht 700	Baht 1,100
Mar	Baht 800	Baht 1,250
Apr	Baht 800	Baht 1,370
May	Baht 900	Baht 1,450
Jun	Baht 1,200	Baht 1,500
Jul	Baht 1,300	Baht 1,500

We selected Suphan Buri price as reference data due to the location that closed to the Case study Company. Hence, the average price for 7 month is amounting to Baht 1,321

Boiler and Turbine power generator

According to City Lion Co., Ltd estimation, the Boiler and Turbine power generator required rice husk 550 kg/hr. which equal to 3,854.4 ton a year. This cost approximately Baht 5,091,662.4.

Gasification generator

According to enquiry data from Shangqiu Haiqi Machinery Equipment Co., Ltd., it is appearing that the Gasifier required average fuel at 500 kg/hr. which would amount to 3,504 tons per year. This cost approximately Baht 4,628,784.

In summary, the cost of maintenance would be as shown in Table 4-10.

Table 4-10 Operation and maintenance cost

<table>
<tr><th></th><th>Description</th><th>Gasification (Baht)</th><th>Boiler and Turbine (Baht)</th></tr>
<tr><td>Fixed O and M</td><td>Spare part</td><td rowspan="2">250,500.00</td><td rowspan="2">306,000.00</td></tr>
<tr><td></td><td>Maintenance cost</td></tr>
<tr><td></td><td>depreciation</td><td>668,000.00</td><td>680,000.00</td></tr>
<tr><td></td><td>overhead cost</td><td rowspan="2">216,000.00</td><td rowspan="2">216,000.00</td></tr>
<tr><td></td><td>wage</td></tr>
<tr><td>Variable O and M</td><td>fuel</td><td>4,628,784.00</td><td>5,091,662.40</td></tr>
<tr><td></td><td>electrical and water</td><td>100,000.00</td><td>100,000.00</td></tr>
</table>

Refer to table 4-10; the fixed Operation and Maintenance cost is acquired from EGAT document which date back to 2013. As such, we had to apply inflation rate to convert cost to present value. According to Bank of Thailand and inflation rate on table 6, the inflation rate for year 2014 is 2.18%.

Hence the Operation and Maintenance cost would be detail as Table 4-11:

Table 4-11Summarise of operation and maintenance cost

Description	**Gasification (Baht)**	**Boiler and Turbine (Baht)**
Fixed O and M	Baht 1,159,232.10	Baht 1,228,203.60
Variable O and M	Baht 4,728,784.00	Baht 5,191,662.40

The usage age of gasification power generator is 25 years while boiler and turbine power generator is 30 years. Hence, the Operation and Maintenance cost for their entire usage life is as illustrated in Table 4-12.

Table 4-12 Estimation of Operation and maintenance cost

Year	Gasification (Baht)		Boiler and Turbine (Baht)	
	Fixed O & M	Variable O & M	Fixed O & M	Variable O & M
1	1,159,232.10	4,728,784.00	1,228,203.60	5,191,662.40
2	1,159,232.10	4,831,871.49	1,228,203.60	5,304,840.64
3	1,159,232.10	4,937,206.29	1,228,203.60	5,420,486.17
4	1,159,232.10	5,044,837.39	1,228,203.60	5,538,652.76
5	1,159,232.10	5,154,814.84	1,228,203.60	5,659,395.39
6	1,159,232.10	5,267,189.81	1,228,203.60	5,782,770.21
7	1,159,232.10	5,382,014.54	1,228,203.60	5,908,834.61
8	1,159,232.10	5,499,342.46	1,228,203.60	6,037,647.20
9	1,159,232.10	5,619,228.13	1,228,203.60	6,169,267.91
10	1,159,232.10	5,741,727.30	1,228,203.60	6,303,757.95
11	1,159,232.10	5,866,896.95	1,228,203.60	6,441,179.87
12	1,159,232.10	5,994,795.31	1,228,203.60	6,581,597.59
13	1,159,232.10	6,125,481.85	1,228,203.60	6,725,076.42
14	1,159,232.10	6,259,017.35	1,228,203.60	6,871,683.09
15	1,159,232.10	6,395,463.93	1,228,203.60	7,021,485.78
16	1,159,232.10	6,534,885.04	1,228,203.60	7,174,554.17
17	1,159,232.10	6,677,345.54	1,228,203.60	7,330,959.45
18	1,159,232.10	6,822,911.67	1,228,203.60	7,490,774.37
19	1,159,232.10	6,971,651.14	1,228,203.60	7,654,073.25
20	1,159,232.10	7,123,633.14	1,228,203.60	7,820,932.04
21	1,159,232.10	7,278,928.34	1,228,203.60	7,991,428.36
22	1,159,232.10	7,437,608.98	1,228,203.60	8,165,641.50
23	1,159,232.10	7,599,748.85	1,228,203.60	8,343,652.48
24	1,159,232.10	7,765,423.38	1,228,203.60	8,525,544.11
25	1,159,232.10	7,934,709.61	1,228,203.60	8,711,400.97
26			1,228,203.60	8,901,309.51
27			1,228,203.60	9,095,358.06
28			1,228,203.60	9,293,636.86
29			1,228,203.60	9,496,238.15
30			1,228,203.60	9,703,256.14
Total	**28,980,802.50**	**154,995,517.31**	**36,846,108.00**	**216,657,097.42**

Refer to Table 4-12, we could conclude that the fixed cost for gasification power generator is Baht 28,980,802.50 and Baht 154,995,517.31 for variable cost. While the Fixed cost for boiler and turbine power generator is Baht 36,846,108.00 and Baht 216,657,097.42 for variable cost.

In conclusion, the cost per unit for each type of generator would be calculated by based on assumption below:

Power generation 500 KW.hr
Operation time in a year 7,008 hours
Average plant factor 80%

The result is as shown in Table 4-13 as follows:

Table 4-13 Conclusion of Operation and Maintenance cost

Description	Fixed O & M	Variable O & M
Gasification power generator (Baht)	28,980,802.50	154,995,517.31
Per unit (Baht/KW.hr)	0.41	2.21
Boiler and turbine power generator (Baht)	36,846,108.00	216,657,097.42
Per unit (Baht/KW.hr)	0.44	2.58

4.2.3 Salvage value

According to EGAT, these machine and equipment after end of usage age, there would be no economic value. It is due to the equipment would be unable to reuse at all.

4.2.4 Social cost

The cost arises from affection of the project cause to social and neighbour area. It might be pollution, environment, and disturbing the daily life of local. However, in this case Study Company, the size and location of power generator is not huge enough to influent to neighbour area.

Chapter5 Conclusion and recommendation for further study

This thesis reports the details of the viability analysis of rice husk power plant for rice miller. It developed based on information of Case study company who has re-enter the business, they left long years ago from emerge of city area. The objective of this research is to develop the concept design of biofuel power generation in order to reduce the cost of production by generate electricity from waste by product. We collected data and identified the criteria of alternative option and selection the best option that suit the situation the most. The research mainly applied and utilized life cycle cost as decision making tools and used the analysis to identify the worthiness of the project.

We discuss with manager of the case study company about the scale of power generator. Although, they show interested to embrace this project but due to the case study company recently established, they have financial constraint. They enquire the cost of machine and equipment from their closed supplier, City Lion Co., Ltd.

They interested in 500 KW biomass power generators and plan to construct the building for housing power generator at the empty space next to husk silos and use pneumatic conveyor to deliver the husk. We collected constraint from Case Study Company and review the appropriate technology for this case. For the cost analysis, we compare 2 type of biomass power generator. First is boiler and turbine power generator and second is gasification power generator. Both of them used the same biofuel which is rice husk. The difference between these two types of generators start from efficiency, fuel consumption, equipment required, system design, and many more, but in this research we would focus on the life cycle cost analysis. The life cycle cost could derive in 4 categories as follows:

- Capital recovery cost
- Operation and maintenance cost
- Salvage value
- Social cost

5.1 Life Cycle Cost

We identified these cost to optimise the lowest cost for power generator. The detail for each power generator type is illustrated in Table 5-1:

Table 5-1Conclusion of life cycle cost analysis for power generators

Description	Gasification		Boiler and Turbine	
	Unit cost	Amount	Unit cost	Amount
Capital cost	0.0335	18,433,023.17	0.0326	22,133,023.17
Cost of operation and maintenance				
- Fixed cost	0.41	28,980,802.50	0.44	36,846,108.00
- Variable cost	2.21	154,995,517.31	2.58	216,657,097.42
Salvage value	-	-	-	-
Social cost	-	-	-	-
Total	2.66		3.05	

According to EGAT, these machine and equipment after end of usage age, there would be no economic value. It is due to the equipment would be unable to reuse at all.

While social cost is nil due to the scale of the power generator which not large enough to affected environment or neighbour area.

Thus, we can concluded that

- The Gasification power generator has lifecycle cost amount to 2.66 Baht/KW.hr.
- The boiler and turbine power generator has lifecycle cost amount to 3.05 Baht/KW.hr.

Hence, the gasification power generator has lowest life cycle cost.

5.2 The revenue from power generation

According to Electricity Generating Authority of Thailand, (EGAT), they had set rate of purchasing electrical power as illustrated on Table 5-2.

Table 5-2 Rate of electricity power purchasing by

Voltage	Time of use Rate	
	Peak	Off-Peak
230 KV	3.0227	2.0173
69-115 KV	3.2504	2.0198
At the end of the line 69, 115 KV	3.6781	2.0412
11-33 KV	3.8548	2.0424

The Peak is during 0900 – 2200 hours from Monday – Friday
The off-peak is during 2200 – 0900 hours from Monday – Friday
And 0000 – 2400 hours from Saturday – Sunday

The purchasing rate for electricity at 11-33 kV is at Baht 3.8548 during Peak and Baht 2.0424 during off-Peak. Refer to peak and off-peak period, in a week the Peak period would equal to 70 hours, while off-peak would equal to 98 hours. If the production is 24 hours, in the whole week the production time would be 168 hours in total. Hence, the percentage of peak period per week is equal to 41.67% while off-peak equal to 58.23%. Therefore average price per unit is 2.796 Baht/unit.

There is a policy to support the VSPP, very small power producer, (scale not above 10 MW) that used renewable energy. EGAT would pay extra adder for these VSPP. The rate is as shown on Table 5-3.

Table 5-3Adder from EGAT (MEA http://www.mea.or.th/)

Fuel	**Description**	**Adder (Baht/KW.hr)**
Biomass	≤1MW	0.50
	>1MW	0.30
Biogas	≤1MW	0.50
	>1MW	0.30
Trash	Landfill gas to energy	2.50
	Thermal process	3.50
Wind	≤50KW	4.50
	>50KW	3.50
Small hydro power	<50KW	1.50
	0.5 KW≤ scale < 200KW	0.80

Refer to Table 5-3; for case study Company that uses husk as fuel to generate power the adder would be 0.50 Baht/KW.hr.

In conclusion, the revenue from generate electricity per unit included adder from EGAT would equal to 3.296 Baht/KW.hr.

5.4 Summary

Although the Boiler and Turbine power generator is lower efficiency and uneconomical in this scale but in bigger scale it would practical. It was due to its limitation to used boiler and turbine which both has a high price and required high maintenance while the scale is not appropriate. Although, when we compare the required operation condition and waste control in this system against the gasification, it is far easier manageable and easier to improve efficiency.

In conclusion, it appearing that at the scale of 500 KW power generators, the most appropriate generator is not boiler and turbine but gasification. It was due to efficiency of the system which higher and more compatible for small scale power generator. However, the gasification has come up with dis advantage as follows:

- Gasification is complex and sensitive process

Due to the sensitivity of oxygen and temperature controller on the Gasifier, the efficiency could affect greatly by small mistake on adjustment.

- Limit variety of biofuel supply.

Although, the manufacturer company claim that their machine could operate on all kind and all properties of fuel but it is questionable. As each biofuel had different of physical and chemical properties, the adjustment is required when change the type of supplied fuel.

- The waste from gasification processes such as ash, tarry water is time consuming.

- The synthetic gas properties are varying time by time. It is very hard to control the quality due to the complex of chemical reaction condition.

- The Gasifier has hard strict on biofuel properties such as humidity, grain size and ash content

Inappropriate preparation of biofuel supply would easily cause serious technical problem to Gasifier.

5.5 Recommendation for further study

In research of viability analysis of rice husk power plant for rice miller, we applied Life Cycle Cost evaluation to identified Capital recovery cost, operation and maintenance cost, salvage value and social cost. However, this assumption might not completely accurate because:

- Capital recovery cost:

The cost of land

- Operation and maintenance cost:

Another crucial factor in cost of operation is the price of husk. It is the main influential cost of the whole processes in both generators system. Refer to Table Rice Husk price from Energy for environment foundation. It appears that the fluctuation of price is very high. When comparing the highest and lowest, you will found that there is 26.7% different. The price is swing up and down follow by the time period of harvest. Which means the cost of production for power generation would also swing by this amount. Nevertheless, due to the scale of power generator was small. The rice husk from this case study company is sufficient. However, in case of the bigger scale of power generator, this factor is crucial and required to take into account.

Salvage value:

Although, EGAT state that the machine and equipment would have no value after at the end of its life cycle, but in practical some company would perform overhaul to extended its life.

Social cost:

In this Case Study Company, the scale of power generator is small and have very small effect to environment or neighbour area. But in case of company decide to increase the size of power generator, the social cost is required to take into considered.

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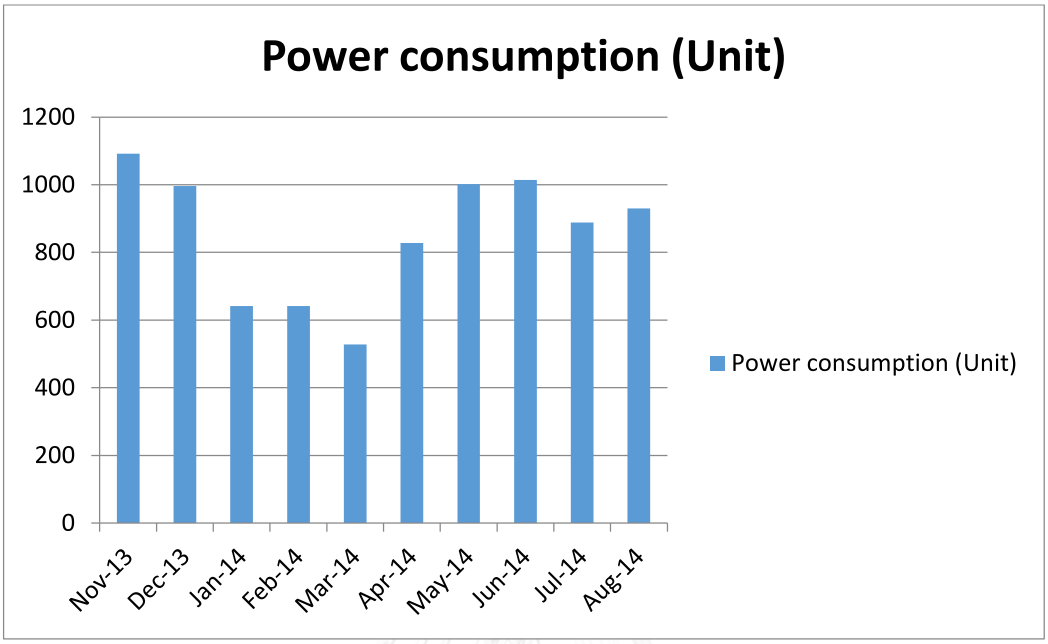
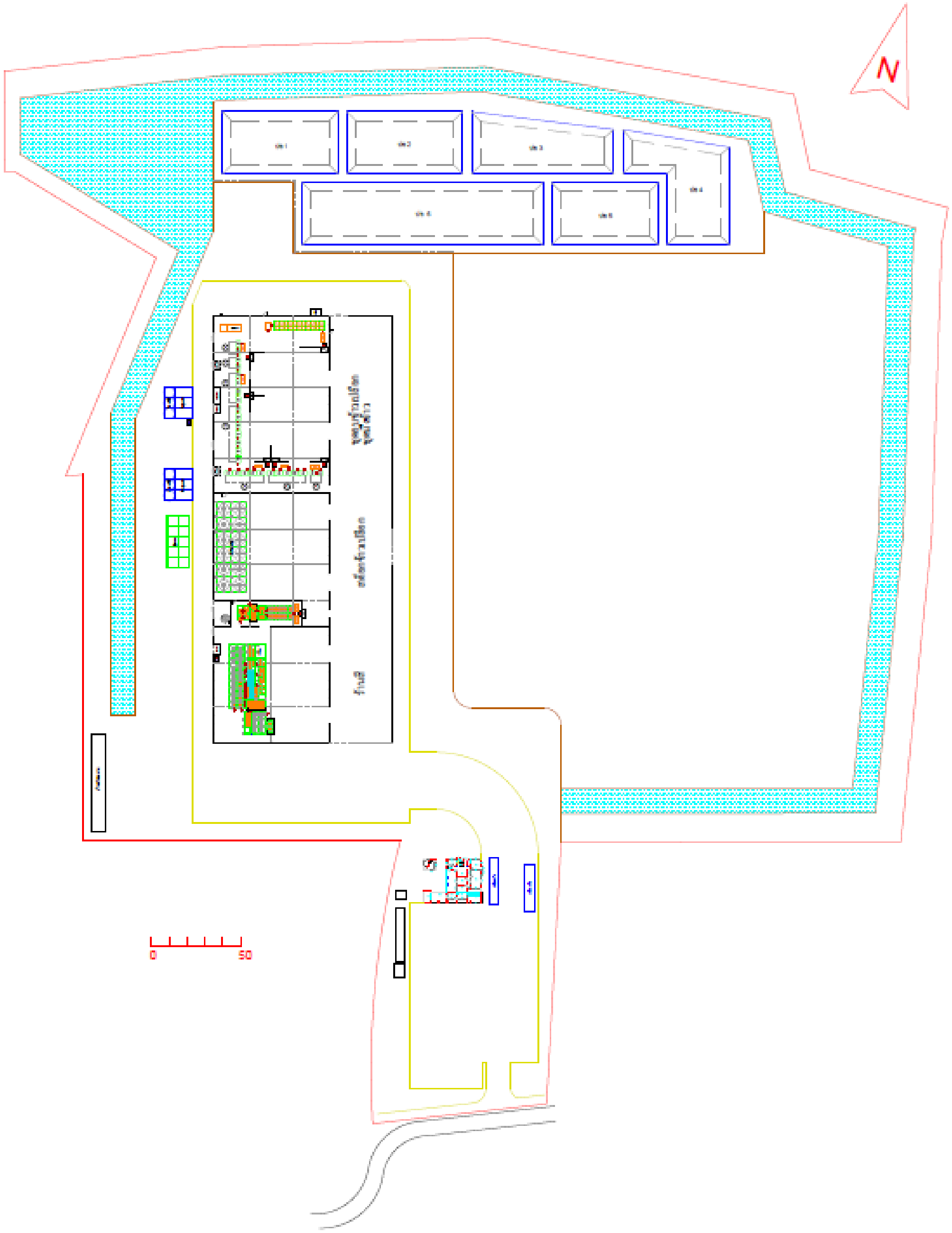
APPENDIX

Appendix A: Power Consumption of Case Study Company

This is record of power consumption in 10 months period. The detail is as follows:



Appendix B: Plant Lay Out



Appendix C: Product range of Case Study Company

Product

The Case Study Company has product as follows:

1. Brown rice

2. Jasmine Rice

3. Parboil rice

Appendix D: Husk Price (2008-2014)

2014	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Jan	1,400	1,000	1,100	400-500	-
	Feb	1,400	700	1,100	400-500	-
	Mar	1,400	800	1,250	500	-
	Apr	1,400	800	1,370	500	-
	May	1,500	900	1,450	600	-
	Jun	1,500	1,200	1,500	600	-
	Jul	1,500	1,300	1,500	600	-
	Aug	-	-	-	-	-
	Sep	-	-	-	-	-
	Oct	-	-	-	-	-
	Nov	-	-	-	-	-
	Dec	-	-	-	-	-
2013	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Jan	1,100	500	800-900	400-500	-
	Feb	1,100	500	800-900	400-500	-
	Mar	1,100	500	800-900	400-500	-
	Apr	1,100	500	800-900	400-500	-

	May	1,100	500	1,000-1,100	400-500	-
	Jun	1,100	500	1,000-1,100	400-500	-
	Jul	1,100	500	1,000-1,100	400-500	-
	Aug	1,300	800	1,100	400-500	-
	Sep	1,300	800	1,100	400-500	-
	Oct	1,300	800	1,100	400-500	-
	Nov	1,300	1,100	1,400	400-500	-
	Dec	1,400	1,100	1,400	400-500	-
2012	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Jan	-	1,000	1,200-1,400	-	-
	Feb	-	1,000	1,200-1,400	-	-
	Mar	-	900	1,350-1,450	-	1,000.00
	Apr	-	900	1,000	-	1,000.00
	May	-	800	800	400-500	-
	Jun	-	700	-	500	-
	Jul	-	-	-	400-500	-
	Aug	-	-	600-800	400-500	-
	Sep	1,100	600	800-900	400-500	-
	Oct	1,100	600	800-900	400-500	-
	Nov	1,100	600	800-900	400-500	-

	Dec	1,100	500	800-900	400-500	-
2011	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Jan	1,000	1,600	1,300	300	1,800
	Feb	1,000	800	1,100	-	1,300
	Mar	1,100	1,000	1,100	-	1,200
	Apr	1,100	900	1,100	-	1,200
	May	1,100	850	1,200	-	1,200
	Jun	1,100	850	1,200	-	-
	Jul	1,100	-	1,500	-	-
	Aug	1,100	-	1,500	-	-
	Sep	1,100	-	1,500	-	-
	Oct	1,100	1,000	-	-	-
	Nov	1,100	1,200	-	-	-
	Dec	1,100	1,000	1,300	300	-
2010	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Jan	1,000	1,000	950	-	1,000
	Feb	900	1,100	1,150	300	1,000
	Mar	1,000	1,100	1,000	-	1,000
	Apr	1,100	1,200	1,100	-	1,000

	May	1,200	1,300	1,100	-	1,000
	Jun	1,100	1,300	1,100	-	1,000
	Jul	1,100	1,300	1,100	-	1,000
	Aug	1,200	1,600	1,100	-	1,400
	Sep	-	-	-	-	-
	Oct	-	-	-	-	-
	Nov	-	-	-	-	-
	Dec	1,000	1,600	1,300	300	1,800
2009	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Jan	900	750	900	300	-
	Feb	900	800	950	300	1,200
	Mar	1,000	700	950	300	1,200
	Apr	1,100	750	950	-	1,200
	May	1,100	750	950	300	1,200
	Jun	1,100	750	850	300	1,000
	Jul	1,100	700	850	300	1,000
	Aug	1,100	750	850	300	1,000
	Sep	1,100	800	900	300	1,000
	Oct	1,100	900	900	300	1,000
	Nov	1,000	1,050	950	300	1,000

	Dec	1,000	1,100	950	300	1,200
2008	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Jan	700	700	800	300	900
	Feb	700	750	800	300	900
	Mar	750	800	900	-	1,000
	Apr	1,100	900	1,000	300	1,000
	May	1,000	900	900	300	900
	Jun	1,000	900	1,000	300	900
	Jul	1,050	1,000	900	300	900
	Aug	1,200	950	850	300	950
	Sep	1,200	900	900	-	1,000
	Oct	1,100	750	850	300	1,000
	Nov	1,100	700	800	300	-
	Dec	900	600	800	300	1,000
2007	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Jan	550	650	950	200	900
	Feb	550	700	900	250	900
	Mar	550	700	850	400	900
	Apr	550	550	850	400	900

	May	650	550	850	300	900
	Jun	700	600	750	-	900
	Jul	750	550	760	300	900
	Aug	750	550	850	300	900
	Sep	750	600	800	300	900
	Oct	750	650	750	300	900
	Nov	700	700	780	300	900
	Dec	650	700	780	300	900
2006	Month	Surin	Kumpaeng Phet	Suphanburi	Chiang Rai	Chachoensao
	Aug	500	500	-	-	-
	Sep	500	550	750	200	1,000
	Oct	700	600	800	400	1,000
	Nov	750	550	680	400	900
	Dec	500	600	750	250	900

Appendix E: Building construction cost estimation by OIC

Building construction cost estimation by OIC

Item	Description	Jun-12			Jun-13		
		Low	Med	High	Low	Med	High
1	single story wooden house	10,100	11,700	13,100	10,120	11,720	13,120
2	2 storeys wooden house	8,700	11,000	12,700	8,710	11,020	12,720
3	single storey lifted basement wooden house	12,700	13,300	14,700	12,720	13,320	14,720
4	Half wooden and concrete house	8,400	10,200	11,500	8,410	10,220	11,520
5	single storey concrete house	11,200	12,800	14,600	11,220	12,820	14,620
6	2-3 storey house	10,300	12,000	14,600	10,320	12,020	14,620
7	single storey double house	9,400	11,200	12,800	9,410	11,220	12,820
8	2-3 storey double house	8,600	10,000	11,200	8,610	10,020	11,220
9	single storey townhouse	7,700	9,200	10,100	7,710	9,210	10,120
10	2-3 storey townhouse 4 m. width	7,600	9,000	10,700	7,610	9,010	10,720
11	2-3 storey townhouse 5-6 m. width without centre pillar	9,100	10,700	12,300	9,110	10,720	12,320
12	2-3 storey townhouse 5-6 m. width with centre pillar	8,000	9,300	11,200	8,010	9,310	11,220
13	1-2 storeys wooden commercial building	5,800	7,200	-	5,810	7,210	-
14	single storey commercial building	5,900	6,500	7,600	5,910	6,510	7,610
15	2-3 storeys commercial building	6,600	7,900	9,100	6,610	7,910	9,110
16	4-5 storeys commercial building	6,400	7,600	8,600	6,410	7,610	8,610
17	not over 5 storeys residential building	10,500	13,100	14,900	10,520	13,120	14,920
18	6-15 storeys residential building	12,700	17,100	20,400	12,720	17,130	20,430
19	16-25 storeys residential building	1,700	21,100	27,300	170,030	21,130	27,430
20	26-35 storeys residential building	18,800	23,800	30,600	18,830	23,840	30,650
21	under 23 m. height commercial building	-	17,200	20,700	-	17,230	20,730
22	over 23m. Height commercial building but not exceed 20 floors	-	19,700	24,900	-	19,730	24,940
23	21-35 storeys commercial building	-	25,500	34,100	-	25,540	34,150
24	3 storeys department store	-	16,500	19,100	-	16,530	19,130
25	over 4 storeys department store	-	22,600	27,800	-	22,630	27,840
26	car park building above ground	9,800	10,600	-	9,820	10,620	-
27	car park building 1-2 basement floor	-	17,600	-	-	17,630	-
28	car park building 3-4 basement floor	-	28,200	-	-	28,240	-
29	warehouse and factory	6,100	7,600	-	6,110	7,610	-
30	tennis court	1,730,000			1,733,000		
31	3 tennis courts	1,440,000			1,442,000		

Appendix F: Electricity Generating Authority of Thailand target energy consumption

Country strategy

According to 10 years period country strategy, Electricity Generating Authority of Thailand had policy to set the target for entire energy consumption to be as follows:

Description	Target		CF	Energy (million unit)		ktoe	
	Previous	Current		Previous	Current	Previous	Current
Wind energy	1,200.00	1,800.00	0.15	1,576.80	2,365.20	134.36	201.54
Solar energy	2,000.00	3,000.00	0.15	2,628.00	3,942.00	223.93	335.90
Aqua energy (small scale)	324.00	324.00	0.35	993.38	993.38	84.65	84.65
Biofuel	1,284.00	-	0.70	7,873.49	-	670.90	
biogas	600.00	600.00	0.60	3,153.60	3,153.60	268.72	268.72
energy from garbage	160.00	400.00	0.60	840.96	2,102.40	71.66	179.15
new energy	3.00	3.00	0.40	10.51	10.51	0.90	0.90

Appendix G: Rate of electricity power purchasing by Electricity Generation Authority of Thailand

Time of use rate

Voltage	Time of use Rate	
	Peak	Off-Peak
230 KV	3.0227	2.0173
69-115 KV	3.2504	2.0198
At the end of the line 69, 115 KV	3.6781	2.0412
11-33 KV	3.8548	2.0424

The Peak is during 0900 – 2200 hours from Monday – Friday
The off-peak is during 2200 – 0900 hours from Monday – Friday
And 0000 – 2400 hours from Saturday – Sunday

The rate above does not included Vat 7%.

For normal user, the average rate of electricity power purchasing is as follows:

บาท/หน่วย

เดือน	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557
ม.ค.		1.7851	1.7268	1.7105	1.7024	1.7012	1.6967	1.6856	1.6471	1.6705	2.6114	2.6220	2.6174
ก.พ.		1.7819	1.7324	1.6954	1.6698	1.7050	1.6704	1.6736	1.6888	1.6545	2.6226	2.5934	2.5902
มี.ค.		1.7485	1.7460	1.7502	1.7163	1.6914	1.6623	1.6965	1.7099	1.7010	2.5834	2.5824	2.5851
เม.ย.		1.7443	1.6617	1.6159	1.5885	1.6377	1.6653	1.6166	1.6051	1.5860	2.5544	2.6053	2.5856
พ.ค.		1.6853	1.6645	1.6655	1.6420	1.6679	1.6146	1.5833	1.6045	1.6332	2.6106	2.5821	2.5275
มิ.ย.	1.7428	1.7600	1.7297	1.7367	1.7095	1.6829	1.6797	1.7025	1.6988	1.7003	2.5754	2.5697	2.5934
ก.ค.	1.7537	1.7738	1.7384	1.6429	1.6165	1.6721	1.6656	1.6583	1.6348	2.5642	2.6070	2.5835	2.6022
ส.ค.	1.7551	1.7178	1.7174	1.7215	1.7201	1.7136	1.6414	1.6387	1.6620	2.6107	2.5865	2.5854	2.5534
ก.ย.	1.7747	1.7928	1.7597	1.7379	1.6856	1.6565	1.7180	1.7065	1.7058	2.6257	2.5806	2.6042	2.6220
ต.ค.	1.7829	1.7522	1.7367	1.6726	1.6743	1.6922	1.6976	1.6649	1.6668	2.5848	2.6119	2.6121	2.6081
พ.ย.	1.7704	1.7194	1.7817	1.7161	1.7161	1.7095	1.6629	1.6815	1.7037	2.6327	2.6320	2.6043	
ธ.ค.	1.7086	1.7047	1.7399	1.6715	1.6522	1.6021	1.6529	1.6674	1.6633	2.5944	2.5186	2.5437	

Average Ft

บาท/หน่วย

เดือน	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557
ม.ค.		0.2429	0.2761	0.4573	0.5744	0.7787	0.6632	0.9098	0.9147	0.8545	-0.0293	0.4062	0.4830
ก.พ.		0.2799	0.4125	0.4600	0.7545	0.7322	0.6895	0.9100	0.9148	0.8545	-0.0293	0.4066	0.4836
มี.ค.		0.3019	0.4260	0.4698	0.7545	0.7322	0.6895	0.9101	0.9148	0.8545	-0.0292	0.4064	0.4838
เม.ย.		0.3018	0.4124	0.4615	0.7545	0.7322	0.6895	0.9100	0.9147	0.8545	-0.0293	0.4063	0.4844
พ.ค.		0.2792	0.3935	0.4456	0.7545	0.7322	0.6895	0.9177	0.9156	0.9373	0.0080	0.3903	0.5666
มิ.ย.	0.2415	0.2864	0.4148	0.4911	0.8568	0.6849	0.6749	0.9177	0.9157	0.9373	0.2808	0.3897	0.5663
ก.ค.	0.1983	0.2809	0.3797	0.4608	0.8615	0.6849	0.6749	0.9177	0.9157	-0.0689	0.2675	0.3896	0.5659
ส.ค.	0.2432	0.2677	0.3958	0.4644	0.8615	0.6849	0.6748	0.9177	0.9157	-0.0689	0.2672	0.3896	0.5654
ก.ย.	0.2403	0.2797	0.4112	0.4833	0.8614	0.6849	0.6749	0.9206	0.9158	-0.0680	0.3990	0.4431	0.5057
ต.ค.	0.2397	0.2923	0.4476	0.5762	0.7788	0.6632	0.7730	0.9206	0.9158	-0.0679	0.3993	0.4434	0.5052
พ.ย.	0.2567	0.2735	0.4643	0.5763	0.7788	0.6632	0.7730	0.9206	0.9158	-0.0709	0.3993	0.4433	
ธ.ค.	0.2394	0.2740	0.4413	0.5764	0.7787	0.6632	0.7730	0.9206	0.9158	-0.0580	0.3994	0.4420	

Appendix H: Operation and maintenance cost for small power plant

The operation and maintenance cost is consisted of fixed cost operation cost and variable operation and maintenance cost. Ministry of energy had research and provide the estimation of these costs for power plant size 500 KW as follows:

Description	Gasification	Boiler and turbine
Spare part	250,500.00	306,000.00
Maintenance cost		
depreciation	668,000.00	680,000.00
overhead cost	216,000.00	216,000.00
wage		
fuel	4,628,784.00	5,091,662.40
electrical and water	100,000.00	100,000.00
Total	5,612,784.00	6,393,662.40

Appendix I: Machine specification

Machine specification

Specification of Biomass Gasifier

Item	unit	HQ-LX180	HQ-LX360	HQ-LX540	HQ-LX720	HQ-LX1200	HQ-LX1500	HQ-LX1800
Fuel	fuel consumption	60-120kg	120-240kg	180-360kg	240-480kg	400-800kg	500-1000kg	600-1200kg
	Fuel required	2cm-8cm wheat straw , rice husk , wood chips, corn cob , cotton straw, pennut shell.......						
	water content	10%-15%						
gasification	capacity	150-180m3	300-360m3	500-540m3	600-720	1000-1200	1300-1500	1600-1800
	composition of gas	CO:20-25% H2:8-15 CH42-4% CO2:2-4% N2:40-45% O2:≤1.0%						
	Rate of Gasification NM3/kg	woody plants:2-3m3 herb plants:1-1.5m3						
Electricity consumption	kw	20kw	30kw	37kw	40kw	55kw	60kw	70kw
Generator	capacity (kw)	50kw	100kw	150kw-200kw	250kw-300kw	400-500kw	600kw-700kw	800kw-900kw

Product Description

AVESPEED 500kw power with wood chips rice husk etc biomass energy plant

Beijing AVESPEED COMMERCIAL &TRADING Co., Limited is also a global leader in the production of biomass gasification equipment, gas generator set, oil filtration and purification equipment etc.
With sophisticated patent technology and expertise.
AVESPEED has developed an internationally acclaimed fluid-bed biomass gasification furnace (patented) product, which efficiently gasifies biomass fuel, such as rice husk, sawdust, woodchips, crop stalk, biogas etc. The pyrolysis gas is used for power generation and other purposes. We also produce 200 different types of oil purification, air-dry generating and SF6 retrieving devices equipment.
Our highly reputable, power plant, mechanical, transportation, petrochemical and military fields products are widely used, with more than 23, 000 sets of equipment currently working efficiently all over the world

Type	LHC-200	LHC-300	LHC-400	LHC-500	LHC-600	LHC-800	LHC-1000	LHC-2000
Rated output power(kw)	200	300	400	500	600	800	1000	2000
Production volume of biomass gas(Nm 3 /hr)	800	1150	1500	1900	2250	3000	3650	6000
Gas temperature of gasification furnace outlet(degree celsius)	700~800	700~800	700~800	700-800	700~800	700~800	700~800	700~800
Gas temperature of the outlet after cleaning and cooling (degree celsius)			< 45					
Consumption of biomass fuel(ton/hr)	0.3~0.36	0.45~0.54	0.6~0.72	0.75-0.9	0.9~1.08	1.2~1.44	1.5~1.8	2.6~3.6
Volume of circulating water flow(m 3 /hr)	6~8	9~12	12~15	17-19	18~23	24~30	30~37	60~75
Gross weight of gasification furnace(ton)	21.8	23.4	26.7	28	30.8	34.8	38.7	90
Ash removing manner			Dry type(Screw-conveyer collection & discharge)					
Device of gas cleaning & cooling system			Cyclone Separator x 2+Spray scrubber x 2+ Venturi scrubber x2+Spray scrubber+Spray Filter(removing dust, tar and cooling)+ Roots Balower+Alkali water washer gas-water Separator					

Appendix J: Adder rate

แบบการขอรับส่วนเพิ่มราคารับซื้อไฟฟ้า (Adder)

สำหรับผู้ผลิตไฟฟ้าขนาดเล็กมาก จากพลังงานหมุนเวียน

วันที่..

ข้าพเจ้า... ได้ยื่นคำร้องในฐานะเป็น..

กิจการ/บริษัท...

สถานที่ตั้งโรงไฟฟ้า...

วันที่คาดว่าจะเริ่มจำหน่ายไฟฟ้าตามสัญญา (SCOD)... และมีกำลังการผลิตติดตั้ง .... kW

☐ น้อยกว่า 100 kW ไม่ต้องวางหลักประกันการยื่นข้อเสนอการขายไฟฟ้า

☐ ตั้งแต่ 100 kW วางหลักประกันการยื่นข้อเสนอการขายไฟฟ้า จำนวนวงเงิน เท่ากับ 200 บาท x ปริมาณไฟฟ้าเสนอขาย ....kW เท่ากับ .... บาท (..) โดยใช้หลักประกัน ดังนี้

○ เงินสด ○ เช็คเงินสด ○ หนังสือค้ำประกันบริษัทเงินทุน/ธนาคาร...

มีความประสงค์ขอรับส่วนเพิ่มราคารับซื้อไฟฟ้า (Adder) สำหรับผู้ผลิตไฟฟ้าขนาดเล็กมาก จากพลังงานหมุนเวียน ดังนี้

เชื้อเพลิง	อัตราส่วนเพิ่ม (บาท/กิโลวัตต์-ชั่วโมง)	เชื้อเพลิง	อัตราส่วนเพิ่ม (บาท/กิโลวัตต์-ชั่วโมง)
☐ ชีวมวล		☐ พลังงานลม	
○ กำลังการผลิตติดตั้ง ≤ 1 MW	0.50	○ กำลังการผลิตติดตั้ง ≤ 50 kW	4.50
○ กำลังการผลิตติดตั้ง > 1 MW	0.30	○ กำลังการผลิตติดตั้ง > 50 kW	3.50
☐ ก๊าซชีวภาพ		☐ พลังน้ำขนาดเล็ก	
○ กำลังการผลิตติดตั้ง ≤ 1 MW	0.50	○ กำลังการผลิตติดตั้ง < 50 kW	1.50
○ กำลังการผลิตติดตั้ง > 1 MW	0.30	○ 50 kW ≤กำลังการผลิตติดตั้ง < 200 kW	0.80
☐ ขยะ (ขยะชุมชน และขยะอุตสาหกรรมที่ไม่ใช่ขยะอันตราย และไม่เป็นขยะที่เป็นอินทรีย์วัตถุ)			
○ ระบบหมักหรือหลุมฝังกลบขยะ	2.50		
○ พลังงานความร้อน (Thermal Process)	3.50		

ข้าพเจ้าขอรับรองว่าข้อความดังกล่าวที่ระบุไว้ข้างต้นเป็นจริงทุกประการ

ลงชื่อ.. ผู้ผลิตไฟฟ้าพลังงานหมุนเวียน

(...)

ตำแหน่ง ....

VITA

Pakkachet Boonyaridh was born on 27th January 1984, Bangkok, Thailand. He was graduated bachelor degree from King Mongkut's Institute of Technology Lardkrabang, faculty of Engineering, majoring in Mechanical Engineering in 2006. He started working with the Royal Thai Army, 2nd Development Battalion, Nakorn Ratchasrima, as a mechanical engineer. After working for three years, he go apply to study Master degree in Engineering Management at Regional Centre for Manufacturing System Engineering (RCMSE), a dual master's degree programme of Chulalongkorn University in Thailand which cooperates with University of Warwick in United Kingdom, faculty of Engineering, major engineering management.