Executive Summary

Study and Promotion on biomass gasification system for small industries

Department of Alternative Energy Development and Efficiency
MINISTRY OF ENERGY

Proposed to

Department of Alternative Energy Development and Efficiency (DEDE)
Ministry of Energy, Thailand

UBON RATCHATHANI UNIVERSITY
October 2009

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By

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Abstract

This report describes the outcome and activities carried out in the project titled "study and promotion on biomass gasification system fro small industries" which is supported by the Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand. Six major activities which are: (1) Surveying, information collection, and literature review about biomass gasification system for thermal application from both domestic and international sources, (2) Surveying on small industries, (3) Study, design, and build the pilot biomass gasification system for the selected factory, (4) Install and test the biomass gasification system individually and coupling with the production process of the selected factory, (5) Suggest the strategy and plan on the promotion of the biomass gasification system using as thermal energy application, and (6) Organize the seminar on the outcomes of the study, are presented.

The most appropriate pilot factory which is Khoa Kor Agro Industry has been selected to implement the demonstrated biomass gasification system for thermal energy. The potential biomasses are dried wood chip and corn cob which are available abundantly in its area. The thermal energy from biomass gases is used to replace the heavy oil in the steam boiler. The 320 kW_{th} biomass gasifier was designed, built, and installed to couple with the current process of the Khoa Kor Agro Industry. The gasifier is a downdraft Inbert type with Double throat section.

From the test, 130 hr of data collection, the biomass gasification system can operate well continuously. The biomass consumption is 28.75 kg/h for dried wood chip and 100 kg/h for corn cob averagely at thermal power of 180 kW_{th}. However, the biomass consumption and thermal efficiency is depended much on the biomass gases production load. In case of using dried wood chip, the thermal efficiency of the gasification system is 72.49% - 95.19%. While the thermal efficiency of the gasification system for corn cob is 70.57% - 89.86%.

In conclusion of the project, the final seminar has been organized on the 12th October 2009, at Chaunchom Resort, Khao Kor, Pethchaboon. There were 140 attendants participating in the seminar. Also, exhibition on energy technology and biomass application were arranged. The demonstration on the pilot biomass gasification at Khao Kor Agro Industry was performed and there were a few attendants show their interests to implement this biomass gasification system to their business.

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Executive Summary

Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand, has researched and developed on the biomass gasification and its application, for many years, continuously. Those are biomass gasification system producing electricity for the rice mills, for non-electrify village (ACMECS project), or producing electricity from biomass gases from palm shell and diesel. For thermal purpose, the biomass gases has been tried to use in the ceramics factories to reduce LPG consumption. Although its heating value is not as high as LPG, it is somehow applicable to some production process with the proper modification. From the survey done by DEDE, there still are a lot of small and medium size enterprises (SME) who are interested in and potential to employ the biomass gasification technology for producing thermal or heat energy in their production process. DEDE has considered that the biomass gasification system for thermal energy is a compact and not-too-high investment cost, therefore it should be worth to study and demonstrate this system to replace the fossil fuel. Also, the promotion and technology transfer plan to the SME should be carried out. Therefore the DEDE has setup the project titled "study and promotion on biomass gasification system for small industries" which composes of 6 major activities as following;

1. Survey, information collection, and literature review about biomass gasification system for thermal application from both domestic and international sources.
2. Survey on small industries by categorizing into 7 groups in order to select the most appropriate factory as a demonstration plant in this project.
3. Study, design, and build the pilot biomass gasification system for the selected factory.
4. Install and test the biomass gasification system individually and coupling with the production process of the selected factory.
5. Suggest the strategy and plan on the promotion of the biomass gasification system using as thermal energy application.
6. Organize the seminar on the outcomes of the study.

The outcomes of the project can be summarized as following;

1. Information survey on biomass gasification for thermal energy

Gasification is a process that converts carbonaceous materials, such as coal, petroleum, or biomass, into carbon monoxide and hydrogen by reacting the raw material at high temperatures with a controlled amount of oxygen. The resulting gas mixture is called synthesis gas or syngas (sometime called producer gas, biomass gas, or wood gas). The synthesis gas itself is a fuel. Gasification is a very efficient method for extracting energy from many different types of organic materials, and also has applications as a clean waste disposal technique.

This process occurs in the limited oxygen condition; therefore carbon monoxide (CO) is the major proportion in the producer gases. Other gases such as methane (CH_4) and hydrogen (H_2) also exist. During the gasification process, there are series of reactions such as combustion, gasification or reduction, pyrolysis, and drying which are separated in different zone in the gasifier as shown in Figure 1.

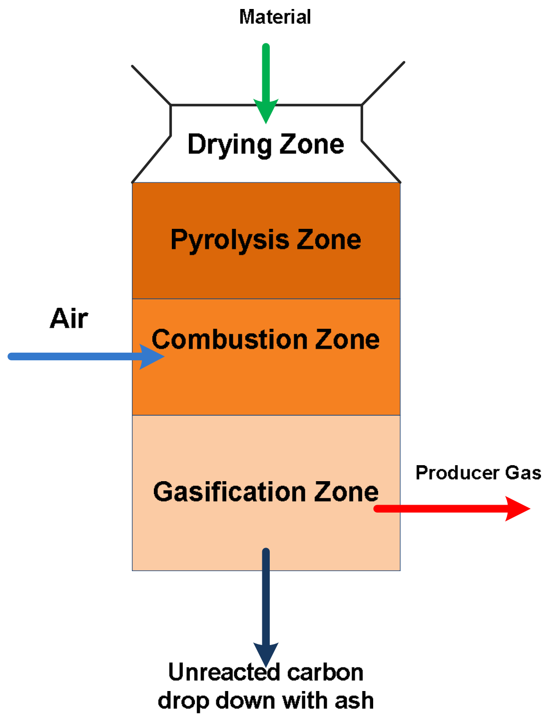

Figure 1 Gasification process in the downdraft gasifier

Types of Gasifier: the gasifier can be classified into 5 types according to the gasses flow passages as followings.

1) Updraft Gasifier

2) Downdraft Gasifier

3) Cross draft Gasifier

4) Fluidized bed Gasifier

5) Suspended Gasifier

1.1 Biomass gasification for thermal energy

From the information survey, it is found that the gasification system for thermal energy is usually a large system which produces thermal energy combined with other fuel such as coal and LPG. The gasifier itself is the CFB (Circulating Fluidized Bed) type. In Thailand, mostly, the gasifier is only small size and produce thermal energy in some food industries for drying or in ceramic factory. Mainly, the downdraft gasifier is used, because it is simple to build and easy to operate while the biomass gases yield is high and low in tar quantity. The maintenance requirement is also low. Therefore, in this demonstration project, the downdraft gasifier is chosen according to the mentioned advantages.

2. Surveying on the small industry and pilot factory selection

In order to choose the most appropriate factory, fitted to our purpose, the factory which utilizes the thermal energy has been classified into 7 groups. From each group, at least three of them will be surveyed for the potential to employ our gasification system appropriately. The survey and selection procedure can be summarized as following;

2.1 Industry category

The small industry is categorized according to the biomass utilization by FAO (Food and Agriculture Organization) in the report titled “Image of Wood and Biomass Energy in Industries in Thailand”. It can be categorized into 7 groups as following;

1) Agro-Processing Industries

2) Food-Processing Industries

3) Metal Processing Industries

4) Forest Products Industries

5) Mineral Based Industries

6) Textile Based Industries

7) Miscellaneous Industries

2.2 Information survey form the department of industry

The department of industry has provided the information about the industries in Thailand. Its data base informs group of industries which can be sourced by name, provinces, and types of industries or TSIC. The consultant has primarily surveyed the information, then selected and contact the possible factory to perform the survey and discuss about the implementation.

2.3 Criteria for the pilot factory selection

In order to select the most appropriate and potential factory to join this project, the consultant has setup the criteria, proposed, and agreed by the DEDE. Six final criteria used in the selection process are;

1. The selected factory must agree to in-corporate with DEDE and allow to install, modify, and test the system with its production process. The selected factory will be a demonstration plant which is able to visited by others. The selected factory must sign the MOU (Memorandum of Understanding) with DEDE to take care the system and operate the system regularly.

2. The location must be appropriate and easy to access.

3. Availability of the biomass fuel. There must be enough supply of the biomass.

Note: If the surveyed factory fail to pass one of item no. 1,2, or 3.Such factory will be accounted as in-appropriate one and will not be in consideration any more.

4. Thermal energy requirement

The selected factory must require for thermal energy as a major consumption. The thermal energy rate should be around 150-200 $kW_{thermal}$ which is about the thermal power of the designed biomass gasification system. If the thermal energy is replacing the LPG or fossil fuel, it will be favorable.

5. Supply and amount of biomass, including transportation. The availability should be at least 52 kg/h (for dry wood) or equivalent.

6. Technical staff

The selected factory must own the technical staff who can handle, at least, simple mechanical skill, electrical skill, and heating system operation. The biomass gasification will be trained to the staff. However, he should be able to take care the whole system afterwards.

2.4 Survey result and pilot plant selection

The consultant has performed the survey for more than 30 factories around the countries. From the surveyed information and the setup criteria, there were 2 most appropriate factories which are the Buranapa group (Wood factory) and the Kho Kor Agro Industry. The Buranapa group is the wood factory which has a lot of small wood pieces available from its production process. It needs thermal energy to dry or bake the wood pallet (product), while it currently uses the direct combustion in the low-efficiency combustion chamber. The Kho Kor Agro industry produces the dried agro-food and herbs, and also fruit juice. It currently uses an over-size boiler which consumes huge amount bunker oil to utilize steam in its heating process. The biomass gasification may overcome its problem if the appropriate modification is applied. Therefore, the final decision has been made to the **Kho Kor Agro Industry** due to its potential of energy saving, biomass availability, fitted integration to our biomass gasification system.

3. Design and build of the biomass gasification system to fit with the selected factory

After the appropriate site or factory has been chosen, the consultant has designed the biomass gasification system according to the information and process requirement of the selected factory (Kho Kor Agro Industry). The system implementation has been designed by the co-operation of the Kho Kor Agro industry and the consultant, before the modification is carried out. Then size of the gasifier and thermal output can be estimated.

3.1 **Principle and design concept**

Based on the biomass availability in the area and the thermal power requirement, the downdraft gasifer capacity of not more than 300 kW_{th} is designed. The major biomass input for the gasifier is the corn cob and dried wood chips.

The Inbert type gasifer which is based on the Swedish design is used. The gasifier is a Double Throat Downdraft Gasifier

3.2 Major parameters calculation

Type: Imbert Type (with heart constriction ring)

Design Condition:	Heating value of biomass gases	4,800.00 kJ/m^3
	Thermal power output	300.00 kW_{th}
	Safety factor (Oversize)	320.00 kW_{th}
	Maximum thermal power output	320.00 kW_{th}

A. Biomass consumption

Thermal power output	320 kW_{th}
Thermal efficiency of the biomass gasification	70 *percent*
i.e. biomass consumption (at Full load)	457.14 kW_{th}
Heating value of corn cob (at moisture content 40%)	11,000.00 kJ/kg
or	149 *kg/h*
Biomass gases flow rate	240 m^3/h

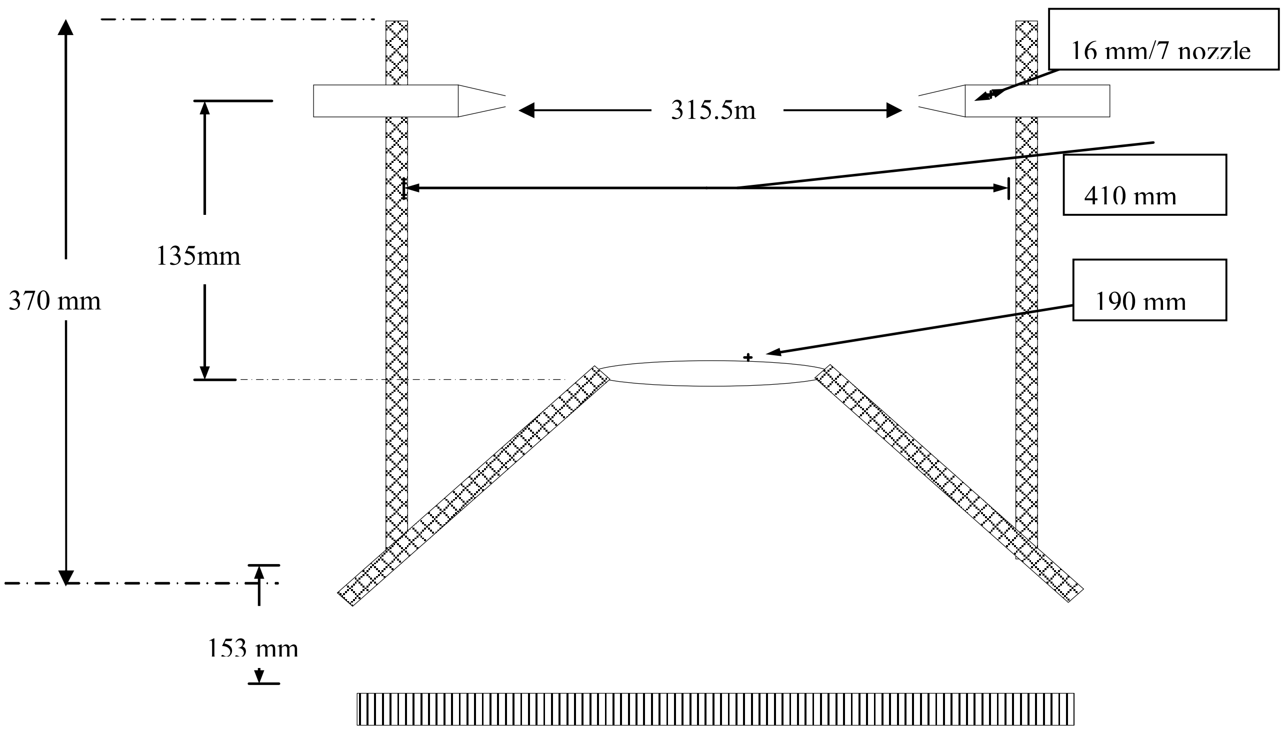

Figure 2 Dimension of combustion and gasification zone

B. Gasifer dimension

The most important dimensions of the gasifer which is the combustion and gasification zone shown in Figure 2. Figure 3 shows the overview, structure, and components of the biomass gasifier.

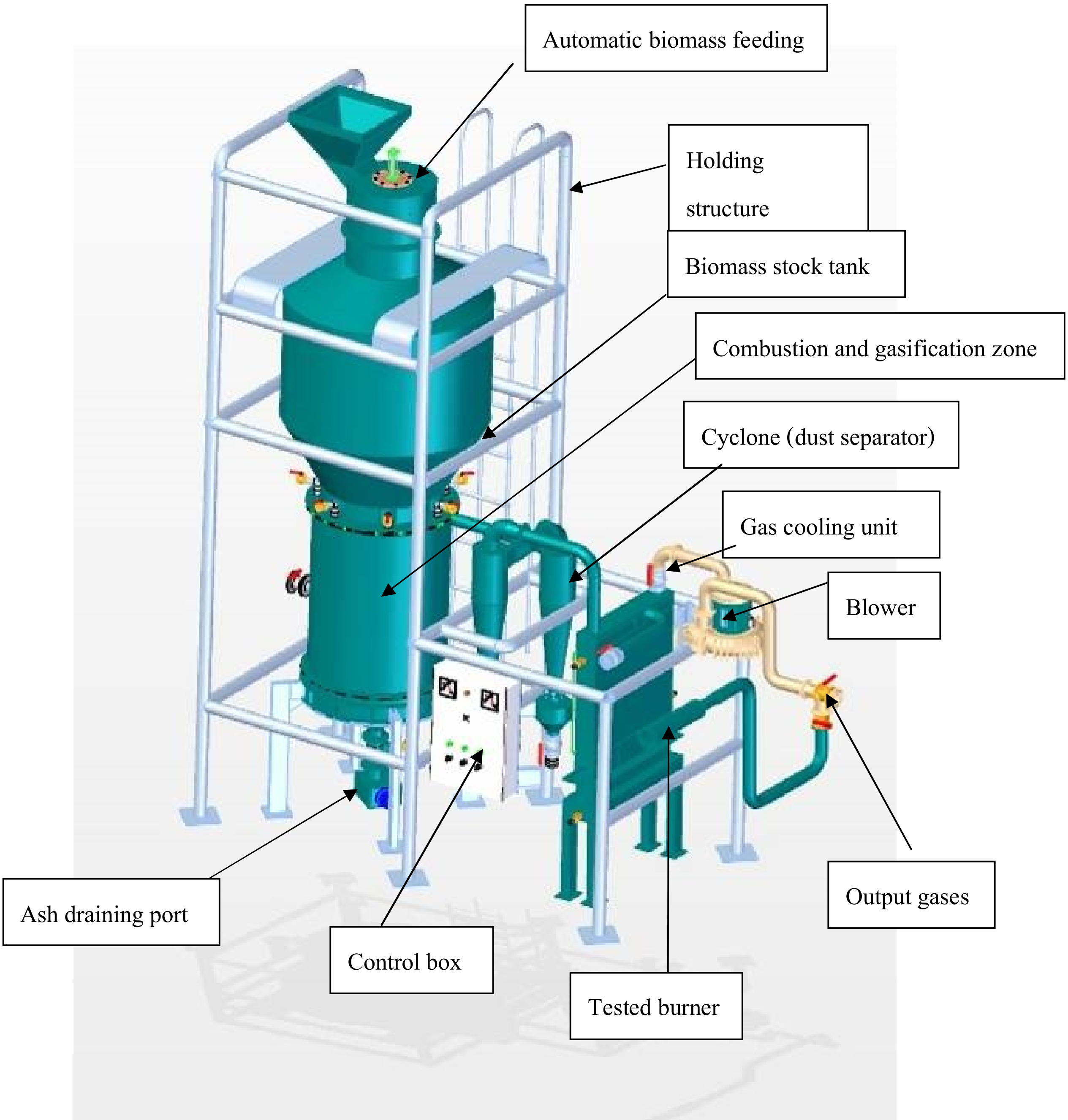

Figure 3 Overview and structure of biomass gasifier

4. Gasifier Installtion, Testing and Analysis

4.1 Installation Work

The gasifier system that was initially tested from the fabricated factory was moved to Kao Khor Argicultural Industry Co., Ltd. on August 25, 2009 (fig. 4). The installation and the thermal system's modification, therefore, were started immediately after the arrival of the gasifier (during August 25, 2009 to September 15, 2009). The installation work consists of 3 main parts, the gasifier installation, the installation of biomass handling and feeding system (fig. 5), and the modification of existing thermal power system. The aim of the modification is to make the existing system ready for generate thermal power from producer gas.

Figure 4 The installation of the gasifier stove

Figure 5 The gasifier system with its biomass handling system

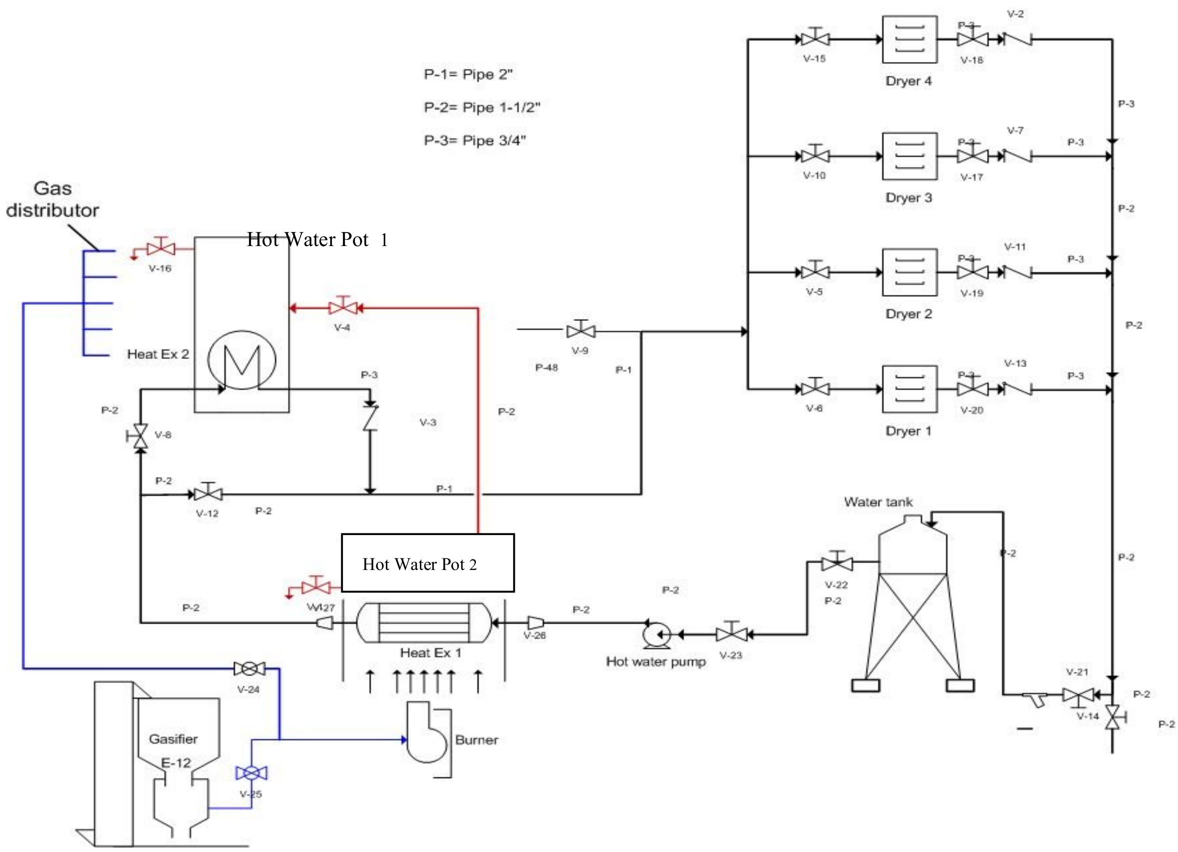

Figure 6 Flow diagram of the modified thermal power system for drying process

From figure 6, the operation of modified thermal power system for drying process of the Kao Khor Argicultural Industry Co., Ltd. can be described as follows.

Previously, a steam boiler was used to produce thermal energy for drying process of the factory such as drying herbs. To generate the steam, the boiler required fossil fuel oil. Producing the steam 8 hours per day, the boiler consumed approximately 700 liters of fuel oil.

For the modified thermal power system, thermal energy is generated by burning the mixture of air and producer gas obtained from the gasifier. The burning heat is first transferred to exchange the heat with circulating water inside the fire tube heat exchanger (Heat Ex.1). Hot water from the fire tube heat exchanger is forced to flow through a water-to-water heat exchanger (Heat Ex. 2), so that the temperature of water inside a hot water pot of the drying process room (Hot Water Pot1) is raised above 60 to 70°C. After heating the water in the Hot Water Pot 1, the remaining heat of the hot water exited from Heat Ex.2 is then flow and heat air in 4 hot air dryers (Dryer 1,2,3,4). The temperature up to 60 to 70°C of room air inside the hot air dryer can be reached. After exiting the heat exchange devices in the hot air dryers, warm water flows up to the water tank tower which is installed at a level of 6 meters above the ground. Finally, warm water flows back to a multi-stage pump to complete the cycle. Part of the heat that generated by burning the producer gas and air is utilized for heating water in a hot water pot outside the drying process room (Hot Water pot 2). This hot water pot was installed on top of the fire tube heat exchanger (Heat Ex. 1).

4.2 Gasifier Testing

Gasifier testing was conducted during September 20, 2009 to September 30, 2009. The testing is divided into 3 testing periods. The 1st period is a 5 hours preliminary test of the system prior to onsite transportation. The 2nd period is the 30 hours operation testing using a test burner. The final period is the test that performs 100 hours of producing and utilizing thermal energy from the producer gas.

1) The preliminary test from the manufacture. From a single test run showed that all the equipments worked normally. The gasifier produced biomass gas that can be combusted as shown in Figure 7.

2) The second period testing at 30 hours, using an external test burner to test the readiness of the machine before actual use. The gas temperatures at various points of the system, the gas flow rate, and the biomass consumption were collected and analyzed.

Figure 7 Flame from a test burner (1st period of test)

1) In the final period, the test method was the same as in the second period. However, in this period, the produced thermal energy was applied to use in the actual process of the factory as shown in Figure 8. The gasifier's thermal efficiency was evaluated at specified gas flow rate. A measurement of electrical power used to produce biomass gas was collected.

Figure 8 Conversing the producer gas to generate thermal energy for production process

4.3 Test Results and Analysis

a) Produces gas analysis

Components of biomass gas produced by the use of wood charcoal as fuel are H_2 7.2362%, CH_4 5.6448%, CO 19.5324%, O_2 7.9742%, CO_2 9.0043% and N_2 50.6081%.

Heating value of biomass gas produced from wood charcoal is **HHV = 5273.41 kJ/m^3.**

Components of biomass gas produced from the cobs are H_2 15.7415%, CH_4 6.4951%, CO 17.6835%, O_2 4.745%, CO_2 3.9184% and N_2 51.4165%.

Heating value of biomass gas produced from corn cobs is **HHV = 6260.08 kJ/m^3**
It was found from the analysis that these heating values are close to the basic calculated value given in the design of the gasifier stove.

b) Biomass fuel consumption

Consumption of biomass fuel for both wood charcoal and cob were test at specified biomass gas flow rate of 75, 83, 90, 100, 110, 124 and 135 m^3 / h, respectively. It was found that at a higher gas flow rate, the gasifier consumed more biomass fuel. At the same value of gas flow rate, the producer gas from wood charcoal provided higher thermal energy and consumed more biomass fuel compared to that of the producer gas from the cob. At the gas flow rates of 124 m^3/ h, the biomass gas produced from wood charcoal provided thermal energy of 181.53 kWth and consumed wood charcoal at a rate of 28.75 kg/h. While at the same gas flow rate, the biomass gas produced from the cob provided thermal energy of 215.62 kWth and consumed cob at 100 kg / h.

c) Electricity Consumption (full load)

The electrical energy used for producing biomass gas was measured. The highest value consumption was found to be 20.61 kWh per day.

d) Replacement rate of fossil fuel

In this project, the gasifier system was designed to produce enough thermal energy for the whole drying process without using the combination of fossil fuel. Hence, the use of biomass gas to produce thermal energy can replace 100% of fossil fuel.

e) Thermal efficiency

The following results show the gasifier's thermal efficiency when using different biomass fuel.

- Wood charcoal: Thermal efficiency of 72.49% - 95.19%.
- Cob: Thermal efficiency of 70.57% - 89.86%

For both cases, a higher thermal efficiency was found when operating the system at a lower gas flow rate.

f) Economics analysis

The following economics analysis is presented for a herb drying process.

If the production capacity is at 100% of the installed capacity (500 kg of fresh herb per day), the profit is 713,400 baht a year, break even point is 1.47 years, the investment rate of return (IRR) is 67.91 percent (compared to the production using the conventional steam boiler).

If the production capacity is at 70% of installed capacity (350 kg fresh per day), the profit is 235,680 baht a year, break even point is 4.46 years, the investment rate of return (IRR) is 21.19 percent (compared to the production using the conventional steam boiler).

To make the production profitable, the minimum production capacity should be at least 55.2% or 276 kg (fresh herb) per day.

g) Environmental impacts

Form the exhaust air's quality measurement; it was found that the quantity of carbon dioxide is relatively low. It can be eliminated by tree planting around the factory.

There are only a few moving components in the system, such as, a mechanical pump, and an air blower. These devices produce very low level of noise that is not annoyed or causes any impacts to the workers.

The main biomass fuel of the project is corn cobs, which is an agricultural waste material. The use of cobs instead off using wood chips will not affect the amount of forest in the country.

5. Strategic plan and suggested measures to promote the use of biomass gas for thermal energy production.

To promote the use of biomass gas for thermal energy production, a strategic plan were proposed. This strategy was set under the Energy Strategy On Renewable Energy issued by the Bureau of Policy and Strategy, Office of Permanent Secretary, Ministry of Energy and under the 15 years (2551 -2565 BC) Renewable Energy Development Plan(REDP). Before the strategy plan was proposed, the SWOT analysis was used as a tool to analyze strengths, weaknesses, opportunities and barriers of the project. The following are important strategies.

5.1 Promotion of research and technology development strategy

This strategy focuses on the brainstorming of researchers from several sectors in relevant fields of technology. The purposes are to achieve together the integration of knowledge and to analyze the technology in a comprehensive overview (life cycle analysis) covering aspects of energy, economics, and environmental impacts. This is to enhance the technology to be competitive with other technologies in energy markets with fully and continuously supports from the government budget.

5.2 PR strategies and campaigns to educate biomass gas technology

This strategy focuses on providing correct knowledge and understanding about the biomass gas technology. And disseminate knowledge of biomass gas technology for all sectors of the public. The purpose is to gain the demand of use, before seriously applied the technology. The spread of knowledge can be done through various channels, such as, training or seminars, media, television, books, journals, etc..

5.3 Promotion strategy of gasifier machine components' manufacturing within the country.

This strategy focuses on educating entrepreneurs who are interested in manufacturing the gasifier components. The aim is to couple research and development together with actual production-oriented. This will bring together the researcher and the manufacturer to exchange knowledge and experience. Thus, enable the development of technology and production standard more quickly.

5.4 Promotion strategy on using biomass gas production.

This strategy focuses on supporting technology, partial investment, knowledge and various benefits to entrepreneurs who are interested in using gasifier technology for their industries. To widespread the use of gasifier technology and thus reduce fossil fuel consumption down, the government may support the construction budget or compensation when using the thermal power produced from biomass gas.

5.5 Strategies to create a network of biomass gas user

This strategy focus on creating network, association, or group of interested persons in biomass gas production, such as group of researchers in the university and group of industry that applied the gasification technology for their process. This will urge the exchange of knowledge and experience among the groups. Establish an association to be a center of coordination between the people who are interested in the gasifier technology.

5.6 Strategy to create biomass gasification's experts

Establish groups of biomass gasification's experts, for example, a biomass gasification center of expertise with a pilot plant may be established. Establish a training center to develop expertise in biomass gas. In addition, the test center that can test and certify the quality of biomass gas should also be founded. This can be useful to the researchers and manufacturers associated with biomass gas.

It also introduced some potential industrial groups that biomass gasification could be applied. For example, biomass gasification could be used to provide thermal energy for burning kiln raw products in ceramics industry. In wood industry, the thermal energy provided from biomass gas could be used to kill insects that spawn in wood. For agricultural and food industries, the biomass gas can be used as a heat source for drying products. In textiles industry, it can be used to generate heat for dye bleaching. In addition to the thermal energy, the biomass gas can be used as a fuel to drive the internal combustion engine and can also be used to generate electricity.

6. Conducting a Seminar

The seminar was conducted on October 12, 2009. The objectives of the seminar were to disseminate results of the study and also to promote the use of thermal energy producing from biomass gas for small industrial plants. The seminar was held at Chuan Chom Resort, Kao Khor District, Phetchabun Province. There were 140 participants in the seminar including 5 representatives from the Department of Alternative Energy Development and Energy Conservation and 10 staffs from Ubon Ratchathani University, the consultants of the project. 68 participants were the Government agencies, 20 participants were from private sector and 37 participants were from general public.

The seminar was divided into the 2 sessions. In the morning session, a basic lecture on biomass gasification and the design information of the prototype system were provided as shown in Figure 9. In the afternoon session an observation trip to the Kao Khor Argicultural Industry Co., Ltd., the place where the prototype system is installed (Fig. 10 and 11).

Figure 9 Lecture session provided in a one day seminar

Figure 10 A trip to observe the prototype gasifier

Figure 11 The gasifier exhibition held at Kao Khor Agricultural industry Co., Ltd.

7. **Problems and Obstacles.**

Throughout the project, there are good collaborations from many relevant industrial sectors and organizations, especially, a grateful assistance from Kao Khor Agricultural Industry Co., Ltd. However, there are some problems and obstacles that the factory should realize and take care. Firstly, the issue of biomass solid fuel's management should be planned. During the rainy season, the frequent rain causes the difficulties in preparation the biomass solid fuel. Even though, the biomass fuel is stored in cover housing, moisture in the air would affect the performance and the operation of the gasifier.

Other problems in producing the thermal energy from gasifier are for example, a more complicated of operation compared to the conventional process, more steps of fuel preparation and a longer time to produce thermal energy. All of the issues were informed to executives and workers of Kao Khor Agricultural Industry Co., Ltd. that despite of the process complication, there is a benefit of using the system in term of economic value and return of the investment.

8. Suggestions

This project has focused on enhancing the thermal energy for small industries. The technology has developed continuously. However, with the following limitations, this technology has not been applied widely in Thailand.

1) Lack of knowledge and understanding in the design and the application of the gasifier system.

2) To apply the system to produce thermal energy, modifications of the existing system are required. This eventually needs investment of modification.

3) Currently, there is no market production of biomass gasifier. The technology is not readily available in Thailand's market.

Therefore, if a strategy plan that is proposed in the final report of the project was implemented, the above limitations will be certainly eliminated. Thereby, it will help to promote the sustained use of thermal energy producing from biomass gas in industrial plants.