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SESSION 2: BIOMASS TECHNOLOGY AND MARKET

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Prospects for Application of Biomass Pyrolysis Technology in China

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1.Preface

Biomass is a regenerative substance storing solar energy. All living creatures on earth rely on the transformation of biomass. Utilizing biomass as energy source has a long history. Starting from the recognition of fire, biomass has been utilized by human beings. 60 million years ago, a large amount of biomass was stored under the earth's surface, which underwent thermo-chemical changes and turned into coal, petroleum and natural gas. Therefore, the maximum amount of available coal, petroleum and natural gas can be calculated, and it will not be greater than the total amount of living creatures at that time. That is to say, coal, petroleum and natural gas are special substances that were formed once and they are not regenerative. However, living plants are a regenerative resource (animals being also a kind of biomass are not to be discussed here). So, biomass energy can be developed and utilized in a continuous way.

At present biomass energy is utilized in the following ways:

- Obtaining heat energy through direct combusting;
- Obtaining combustible gas through biomass fermentation;
- Obtaining combustible gas through biomass gasification;
- Obtaining combustible gas, charcoal, tar and other chemicals through biomass pyrolysis;
- Obtaining various chemical raw materials through biomass chemical conversion.

2. Comparison of biomass pyrolysis technology with other biomass energy converting technology

1) Direct combustion and densification of biomass

The direct use of biomass by human beings from ancient times until now has been by burning. This traditional way of using biomass has been gradually replaced by other forms of energy conversion, due to its low rate of heat utilization (less than 13%) and heavy pollution.

Biomass densification is a technology that has been developed in recent years replacing wood and coal. This technology applies mechanical force onto plant bodies transforming them into biomass blocks and bars of greater density after being crashed, dried and heated. The density of such blocks and bars is large, so it can be burned like wooden bars to overcome the disadvantages of burning loose materials.

The process of biomass densification consumes large amounts of energy, so that wooden chips, at the cost of RMB 60 yuan per ton, are transformed into artificial wooden bars of RMB 400 yuan per ton. In this case, direct burning becomes quite uneconomic. At present, most of densified biomass bars are used for the production of artificial charcoal through pyrolytic processing. As the current price of artificial charcoal in the market is between RMB 1,500 and 2,000 yuan per ton, this makes biomass densification processing possible.

2) Biomass fermenting, production of biogas

Under anaerobic conditions, biomass is transformed into a gas mainly containing methane and carbon dioxide (biogas). This is a biochemical process involving biological engineering.

Consuming far less energy is the greatest advantage of biological engineering which uses metabolic energy of germs in the production process. Biogas production is the lowest in energy consumption among various biomass energy conversion options. Biogas contains 50-70% methane and 30-50% carbon dioxide. Being a combustible gas of high quality and medium heat value (lower heat value usually greater than $20MJ/Nm^3$) it is particularly suitable as combustible gas for civil use.

The reason why biogas production can not be spread broadly in the countryside of China mainly lies in:

- In-sufficient sources of nitrogen in biogas production In the course of biogas production, C/N should not be greater than 25, but the C/N of dry stalks (harvested in autumn) is usually greater than 30, such as 87 for dry wheat straws, 67 for dry rice straws and 53 for corn stalks. They are main biomass in the countryside but can’t be used directly in fermenting processes. Biological engineering is applicable only in places where pigs and chicken are raised in a centralized way.

- Biogas-generating tanks for single households do not comply with modern modes of living in China and therefore provide no opportunity for future development. Especially for countries like China with large population and few land resources, garden type agriculture based on single households is by no means a long term policy.

- Biogas production by biological engineering has a great limitation in Northern China because it is low in production capacity and temperature has a great influence on it.

Although problems mentioned above exist, biogas production will not lose its significance for applications in the countryside for quite a long time, especially in areas backward in economy and dispersedly inhabited. It will have more value of application especially in places rich in nitrogen.

3) Biomass gasification

Under the condition that oxidizers are available, biomass undergoes oxidation. This reaction is called biomass gasification because it can oxidize biomass into gaseous substances. More combustible gases like carbon monoxide and hydrogen can be obtained only by controlling the course of oxidation leading to incomplete oxidation. This is the most important approach in biomass gasification.

According to the characteristics of oxidizers, there are the following ways of biomass gasification:

- Gasification using air as the oxidizer
  Incomplete burning of biomass using air as the oxidizer. The main reactions are:

$$C + O_2 \rightarrow CO_2 + Q$$

$$2C + O_2 \rightarrow 2CO + Q$$

Both reactions above are exothermic reaction and there are reduction reactions at the same time:

$$CO_2 + C \rightarrow CO_2 + Q$$

$$C + H_2O \rightarrow CO + H_2 + Q$$

Both reactions above are endothermic reaction.

From the reactions we can see that the produced gas mainly contains CO, a combustible composition (usually 18-23%), H_2 (usually 6-10%), and CO_2 (usually 8-10%). As inert gases exist, the contents of combustible gases are diluted so that the heat value of the gas becomes very low with a lower heat value usually between 3,500 and 5,500KJ/m^3 (some are called hot gas, namely, it has to be preheated for use before being combusted).

Air gas production is a relatively economical and simple way of conversion of biomass energy with the advantage of being fast in gas production, large in production volume and high in utilization rate of energy without any by-product. The biggest disadvantage is that the heat value of the gas produced is low which limits its application.

- Gasification using pure oxygen as oxidizer

The principle of reaction in this way of production is the same as that of air gas producers. As pure oxygen is used instead of air, this reduces the content of nitrogen in the gas so that the content of combustible components are increased. The content of CO is usually between 40 and 50% and the heat value is doubled compared with that of airgas (usually between 10 MJ/m^3). As the combustible gas contains too much CO, safety is particularly important in use.

- Gasification using water as oxidizer

Reactions involving vapour and carbon:

$$C + H_2O \rightarrow CO + H_2$$

Carbon monoxide and hydrogen are produced, both of which are combustible gases. As this water gas reaction is endothermic, preheating of biomass is needed and vapour should be led in for reaction after it being heated to a high temperature. This course preserves heat with reactions happening alternatively, nearly 50% biomass is consumed but less than 50% of charcoal generating water gas reaction is consumed. The lower heat value of water gas is usually between 10 and 12 MJ/m^3 and it is not suitable for civil use because it contains high amounts of CO. Water gas is mostly used in synthesizing ammonia as it is a good source of hydrogen.

4) Biomass Pyrolysis

Biomass is pyrolyzed under condition being free from air, namely destructive distillation of biomass. The resultants of biomass pyrolysis have three states: solid charcoal, liquid wood tar and pyroligneous liquor, combustible gas. According to the temperature in pyrolyzing, the process can be divided into pyrolyzing at low temperature (below 600°C), pyrolyzing at moderate temperature (600 to 900°C) and pyrolyzing at high temperature (above 900°C). Pyrolyzing at different temperatures may produce resultants with different content. The higher the temperature, the greater the amount of combustible gas and liquids, and the less the amount of solid charcoal.

Wood destructive distillation was very popular early in the century for the purpose of producing wood charcoal and ethylic acid for metallurgy, and tended to decline in the middle of the 20th century because of lack of wood and coal and the start of petroleum refining.

Generally, it is regarded that wood destructive distillation is very similar to coal destructive distillation. Herbaceous plants can't be distillated, i.e. the resultants from distillation of herbaceous plants is not the same as that from wood distillation. This point of view is challenged through research results obtained by the Dalian Environmental Science Design & Research Institute. The Institute has successfully made distillation and pyrolyzing tests with more than 20 kinds of biomass like wood chips, leafs, corn stalks, rice straws, soybean stalls, wild grasses, coconuts shells, yellowweed, bagasses, furfural residues, etc. and all resultants obtained from the tests were almost the same. This brings new life to wood destructive distillation, especially in the 21st century when coal and petroleum will come to an end. Then, biomass destructive distillation and the pyrolyzing industry will rise again.

Charcoal obtained from biomass pyrolysis is a kind of charcoal purer than coal coke in both block and powder form. Being low in ash content, good in reactivity and large in specific surface area, it is a high-quality reducer for nonferrous metallurgy, an absorptive agent for the environmental protection industry and a soil modifier for agriculture. It therefore has a broader application than coal coke.

Tar and pyroligneous liquor produced in pyrolysis is a liquid containing more than 200 components, like acetic acid, methanol, acetic aldehyde, acetone, ethyl acetate, etc.. Some components have a value as raw material in the chemical industry.

Resultants produced in biomass pyrolysis mainly contain: CO_2, CO, CH_4, C_2H_4, H_2, etc., with a lower heat value is between 15 and 20 MJ/m^3, therefore belonging to combustible gases of medium heat value. It is called wood gas because its compositions and heat value are similar to urban artificial gas. It is also a gas of high quality because it doesn't contain any sulphide and nitride, and can be used directly as civil combustible gas.

Contents of resultants produced in biomass pyrolysis at temperatures of 900°C:

Wood charcoal: 28 to 30%, wood tar: 5 to 10%, combustible gas: 30 to 35%, pyroligneous liquor: 30 to 35%.

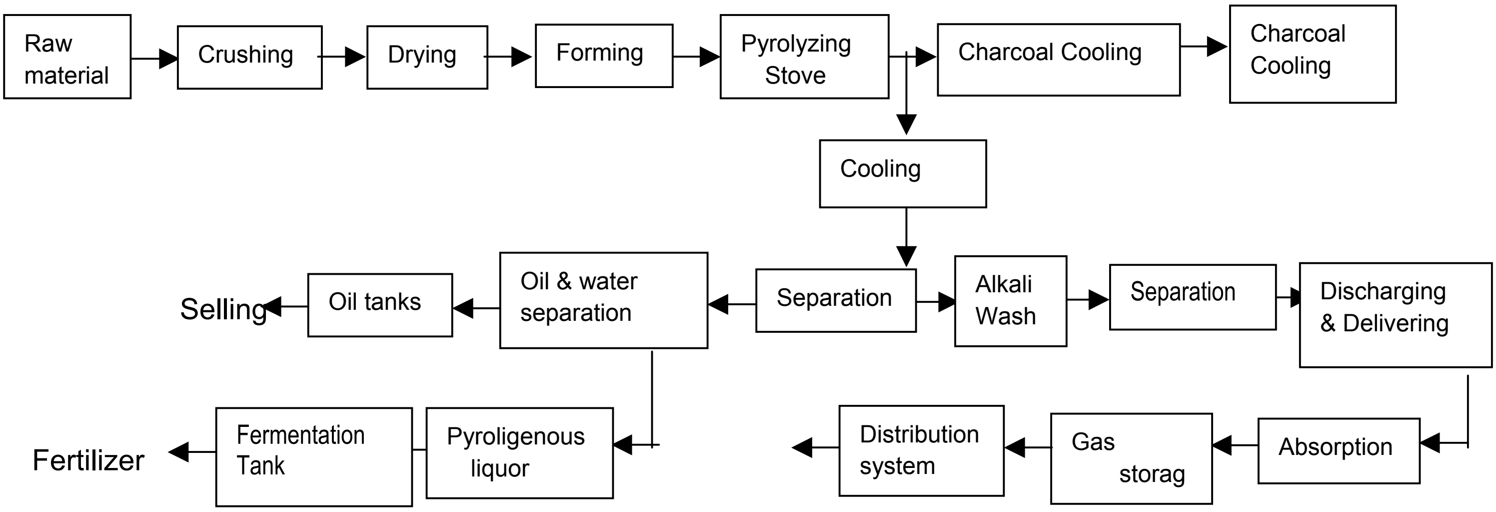
One of the features of biomass pyrolysis is the diversification of resultants. This is both an advantage and a disadvantage. If market are found for the main by-products, great economic benefits can be obtained. If only combustible gas without other by-products is to be used, economics are not favourable.

3. Engineering practice of biomass pyrolysis

A biomass pyrolysis plant had been built in 1995. The designed capacity of gas production was 1500m3/d. Three years later, the plant was moved and rebuilt with doubled capacity. This Sanjianpu Biomass Gas Plant is in operation for 4 years now.

It is the first social practice to use biomass pyrolyzing replacing artificial gas production by pyrolyzing coal to make a continuous supply of pipe gas to the peasants. All design codes, standards, management system and pricing use that of urban artificial gas.

1) Process Flow:



2) Standards for control of product quality

Standards should be in accordance with the technical requirements for artificial gas in Standard GB - 13612 - 92.

	Standard value	**Actual value**
Lower heat value(MJ/m^3) should be greater than	14.7	15 to 20
Foreign substance:		
Tar and dust (mg/m^3) should be less than	10	5 to 10
H2S (mg/m^3) should be less than	20	None
Ammonia (mg/m^3)should be less than	50	None
Naphthalene(mg/m^3)should be less than in winter	50	None
in summer	100	None
Oxygen content (V%) should be less than	1	0.8
CO content (V%) should be less than	10	10 to 15

3) Operating procedure and management systems of the Combustible Gas Plant

There are 20 items, such as “Technical Qualification Requirements for the Workers in Combustible Workshop”, “Operating Procedure of Pyrolyzing Stove”, “Management Rules on Users’ Using Combustible Gas”, “Fire Prevention Systems of the Combustible Gas Plant ”, “Handing of Electricity Shutdown Incident ”, “Handling of Water Supply Stop Incident”, “Handling of Alkali Supply Stop Incident”, etc.

4) Investment of the Combustible Gas Plant

Total investment according to the design was RMB 4.5 million yuan but actual investment is RMB 2.5 million yuan, including 0.9 million for the 1,000 m^3 gas storage tanks, 0.5 million for the main distribution system and branch distribution systems, 0.5 million for the pyrolyzing equipment, 0.5 million for purifying equipment and 0.1 million for others items.

It was planned to charge RMB 2,000 yuan per household as gas source fee, but the actually charged fee was 1,000 per household.

The pricing of combustible gas is RMB 1 yuan/m^3 in accordance with the price of urban gas. Average consumption by each household daily is about 1.3m^3, the same as the average consumption of Dalian inhabitants for many years, namely 2,093.5MJ per person each year.

Ex-factory price of charcoal is RMB 1,600 yuan/ton, and the actual selling price of tar is RMB 3,000 yuan/ton.

5) Economic benefits

Supply of gas for use by 1,000 households, we can have a profit of RMB 0.8 to million yuan each year.

4. Factors that currently limit the spread of biomass energy conversion technology in the countryside

It is clear that biomass energy has advantages in many aspects. Especially the engineering technology of biomass energy conversion by using stalks has advantages of obtaining raw materials locally, utilizing wastes, reducing pollution, increasing energy utilization, being convenient and clean. But why can biomass energy conversion not spread in the vast countryside of China. In the past eight years, several hundred of communities from countryside China contacted the Institute with the request to build gas supply projects in the countryside. But, only three became successful for the following reasons:

1) Limited by the economic situation in the countryside

The economy in the countryside of China is still backward. Food and clothing is still a problem in parts of the regions and the people are concerned with eating, dwelling and wearing in the first place. They are quite satisfied with having enough burning wood and therefore combustible gas is out of question. In places having better living conditions, electricity and tap water supply is starting to be taken into consideration without the intention to change the structure of fuels. In cities there are allowances for gas supply of governments, but who will offer allowance for gas supply in the countryside?

Besides, combustible gas at the price ranging from RMB 1 to 1.2 yuan/m^3 is still unaffordable due to bad economic conditions, and burning grasses and coal are much cheaper.

2) Limited by low living quality in the countryside

Due to the low living quality, the user value of combustible gas can not be fully evaluated. Standards like time saving, cleanliness, less pollution, less hard work, etc. are not included in the evaluation. In some places questions such as " is gas cheaper than stalks?" is raised.

3) Limited by dispersed settlements in the countryside

Today, a vast majority of the population (more than 9 million) in the countryside lives in dispersed settlements. This courtyard style of living brings great difficulty to combustible gas projects and increases investment tremendously.

4) Limited by ideas

Only considering personal economic and short-term interests and disregarding general interests, long-term and environmental benefits. Unbalanced economic development and different views of households, some households are in favour and some against the use of combustible gas.

5. Biomass pyrolysis has a bright future in China's countryside

1) Economy in the countryside is developing very fast and peasants become richer every year. In China, there are nearly 1 million villages, of which 20 thousand villages will improve their standard of living in a way that they will require modern fuels in the near future. Especially in suburbs of big cities and in small towns, living conditions like in cities will be needed very soon due to the fast development of the economy. This will cause them to consider the opportunity of combustible gas.

2) The situation of dispersed settlements in the countryside of China will not last long. China has a relatively large population and little land, it is impossible for the households of courtyard style in the countryside which are disperse and occupy more land to exist for a long time. Households in the countryside of China must be placed in a centralized way in towns. According to the principal of being advantageous to both living conditions and production, it is preferable for size of future towns in the countryside of China being 1,000 to 2,000 households. This will provide advantageous environmental conditions for gas supply in a centralized way by pyrolyzing biomass.

3) Prices of coal and petroleum will rise significantly as estimated by experts. In 2010, the price of artificial gas will be above RMB 5 yuan/m^3, and crop stalks will more and more become discarded. At that time artificial wood gas using stalks as raw materials will be a cheap fuel of high quality and will be doubly welcome.

4) With the modernization of the large industry, new rural industries will come into being. Pyrolysis projects using stalks as raw materials will also require industrial systems to obtain materials locally, such as wood charcoal deep processing industry, tar processing industry, pyroligenous liquor extracting and processing industry. At that time biomass energy converting project will be spread everywhere in the countryside.

5) When a new pricing system is formed at a certain stage of economic development, there will be changes in prices of combustible gas, wood tar and powdered charcoal. At that time, it will be possible for powdered charcoal to be used on farmland (being confined by economic conditions it is impossible now in our country, but in Japan powdered charcoal are being used as soil modifier.)

6) At present peasants have built successively living areas with buildings similar to those in cities on the brink of big developed cities and imitate those living conditions, but they can't have gas supply like cities. Therefore, in these parts linking cities with countryside market, opportunities exist for gas supply projects using pyrolysis of biomass.

Above all, biomass pyrolyzing technology is a mature and excellent applied technology. It is a comprehensive utilization technology being advantageous to environment, society and economy. Though it is rather difficult to spread and popularise the biomass pyrolyzing technology at the moment, its application has a extraordinary bright future in an agricultural country such as China.

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