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Biofuel handling, pretreatment and traffic use in China

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ABSTRACT

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This paper describes the development situation of biofuel in China and the research progress and application in transportation and aviation area, including several key technologies of biofuel production: biofuel pretreatment and handling. This paper is aiming to find the best storing, transmitting, feeding and pretreating methods of various materials, as well as a comparison among the advantages and disadvantages of different pretreatment methods, which is expected to reduce cost in production process and reach the maximized benefits. Meanwhile, a case study of one biomass fuel production factory in China is presented with evaluation and analysis on their technology application.

Forward

At the edge of the completion of my thesis, I would like to spread my gratitude to many people, as this thesis could not be accomplished without their help. First of all, I would like to thank particularly Professor Risto Soukka and Doctor Ville Uusitalo, for instructing me concerning every step of my work and providing patient suggestion and modification, which I benefitted tremendously from. I would also like to thank my parents for the courage that they gave me within the process. At last, many thanks shall be delivered to my friends Aoke Li and Xiaozhou Li for helping me collecting resources. The work will not be accomplished without your help.

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ABBREVIATIONS

DME	Durable medical equipment
HTU	Hydro Thermal Upgrading
COFCO	China National Cereals, Oils and Foodstuffs Corporation
PM	Particulate Matter
MTBE	Methyl tert-butyl ether
ETBE	Ethyl tert-butyl ether
P-M-F	Pig-Methane-Fruit
GTL	Gas to Liquid Fuel
BTL	Biomass to Liquid Fuel
NaOH	Sodium Hydroxide
KOH	Potassium Hydroxide
$Ca(OH)_2$	Calcium Hydroxide
CO_2	Carbon dioxide
IEA	International Energy Agency
OPEC	Organization of the Petroleum Exporting Countries
EIA	Environmental impact assessment
CNPC	China National Petroleum Corporation
GDP	Gross Domestic Product
NO_X	Nitrogen Oxide

1. Introduction

Based on the estimation, fossil energy (coal, crude, natural gas) which counts for 80% of total energy consumption will run out after one or two hundred years (Baidubaike, 2014). The energy crisis is one of the biggest problems the whole world has to face. In addition problems related to environment trouble. For instance Global warming, ocean pollution, desertization which siginificant threatens the survive of mankind (Chen, 2012). The traffic fuels is one of the typical area that confronts these two problem same time. The fossil fuels like oil are expensive and cause huge air pollution problems. To find a cleaner renewable energy to replace the traditional fossil fuels can solve these problems. The biofuel is clean and safe to use which use lignocellulosic biomass as raw material, may became one of the most popular new energy. Based on all these benefit, biofuel can be a good solution for the traffic fuel problem.

China is one of the most important economic entities in the whole world. The energy crisis will bring a serious consequence for this fast developed country. Meanwhile, behind huge economic growth, China faces fatal environment problems which already not just affect itself. Professor Xietian from University of South Carolina says that "Pollution in China is not only a Chinese problem but a global one and more closely it has clearly affected neighboring countries via the form of air and water pollution. After all water circulate around the global and air flows across the boarder as well. " (Xietian, 2012). Another issue which came with China's rapid development is the rapid growth in demand for crude oil. If China's car per capita number matches the level in US, it would consume around 18% of total crude production which would have a significant biological and economical consequence (Sophie, 2013).

This study believes that biofuel as one of the renewable energy can be a great solution for Chinese energy and environment problem in traffic area. So study and analysis the current situation of biofuel in China can help the further development of biofuel and can give a general report for renewable energy firm who want to build potential partnership with China.

This article use literature review and interview as research methods. The study focuses on the production process of biofuel which are used in traffic. In all the product process, handling and pretreatment are very important process steps, will be special analyzed. Two kinds of biofuel have been widely used in China which are fuel ethanol and biodiesel. These two cases will also be analyzed during the study. The concepts, characteristics, exaction methods and developing phases of biofuel are introduced in Chapter 2. Chapter 3 describes the current situation in China concerning biofuel. Chapter 4 describes in details different pretreatment methods of biofuel using lignocellulose as material, as well as their advantages and disadvantages, different methods and effects of biomass material storage, transmission, and feeding. Chapter 5 provides analysis on the Biofuel Use in China Transportation. Chapter 6 provides analysis on the future development of biofuel in China.

2. The concept of biofuel

2.1. Renewable energy

Renewable energy refers energy types that the sources of those kinds can supply unlimitedly. Rigorously speaking, most renewable energies can be comprehended as the transformation and storage of solar energy. On the other hand, fossil fuel, which indeed is the transformation and storage of solar energy, does not belong to renewable energy type, as well as nuclear power. Distinguish with primary energy, renewable energy includes these types: biomass, solar, hydro, wind, tidal, and geothermal energy (Courseware, 2007-2012).

Figure 2-1 present the global energy consumption, ratio of normal and renewable energy, in 2006. Fossil fuels, taking 79% of total amount, are still the main suppliers of the global energy consumption. Nuclear power with 3% of amount get second place, and all kinds of renewable energy gather up take only 18%. Among the consumption of renewable energy, traditional biomass power and large-scaled hydropower encompasses 68.4% and 16.8% of the consumption, respectively. Solar (mainly solar water heater) takes up 7.4%, power stations based on renewable energy (excluding hydropower) is measured at 3.7%, with the remaining biofuel at 3.1% (Qin and Wang, 2009).

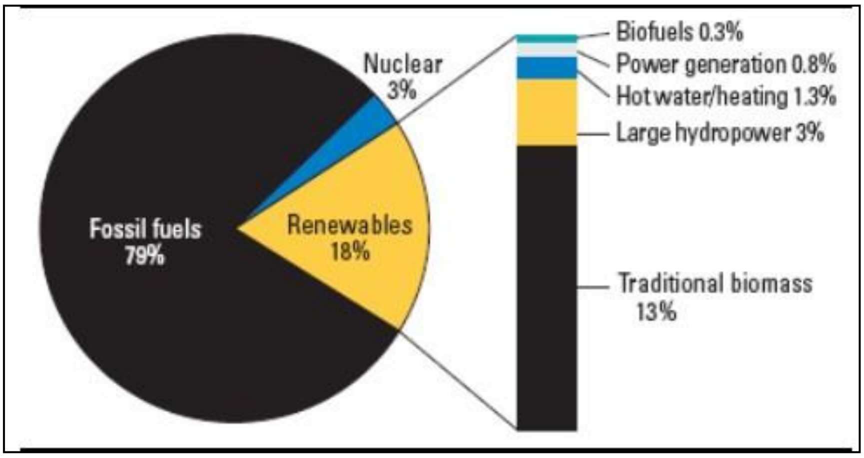


Figure 2-1：The global energy consumption（2006）(Qin and Wang, 2009)

The transitional biomass, which takes around 72% of all kinds of renewable energy, as well as 13% in general compare with all type of energy, can be defined as the most important part of composition.

2.2. Biomass and biomass energy

Biomass is the general term referring to all the biological substances, either alive of dead of metabolites. They include all organisms formed through photosynthesis which contain all animal, plants, microorganisms and their excreta. The solar radiation's power has been trapped by photosynthesis in the form of biomass, which can be produced into kinetic, heat, motion, electric, magnetic, light and other energy forms, to fulfill the human's demand of energy. Agricultural waste, food-manufacturing and lumber-manufacturing scraps, urban litter in solid form, sewage and industrial wastewater can all be defined as Biomass (Market Research of China Chuandong, 2009).

Biomass resources can produce 170 billion tons of dry matter, annually. Therefore, it can offer a huge supply for the usage. Biomass, as a renewable source of energy, is the only renewable source of carbon energy (Market Research of China Chuandong, 2009).

Biofuel is defined as solid, gas or liquid extracted from biomass. Biofuel can be in all three forms of matter. Solid biofuel includes sawdust, firewood, bark, etc; gas formed biofuel includes gases such as methane, dimethyl ether, bio-hydrogen, etc. And lastly liquid formed biofuel includes Bio-ethanol, bio-diesel, liquid bio-hydrogen, methanol, bio-butanol, cellulosic ethanol, synthetic biofuels and so on (Qin and Wang, 2009).
To substitute the various fossil fuels used in transportation, liquidized biofuel receives great attention from academic, political and the business world, it is the most important way of using biomass (Ma, 2012).

2.3. The characters of biofuel

Biofuel and normal fossil fuel have significant difference in energy density, energy consumption and production, the ratio of carbon content, carbon emission, and carbon emission reductions (Qin and Wang, 2009). Generally, even though biofuel is inferior in energy density, but the two are almost identical in energy production, and biofuel's contribution in reducing carbon emission is huge compared to fossil fuels. Adding the fact that biofuel can be easily renewed, biofuel is by far the best alternative to fossil fuel.

Table 2-1. A comparison of commonly used fuels from fossil and biological origins in terms of energy density, process energy cost, carbon ratio in the fuel, carbon emitted and carbon mitigated (Liu and Wu, 2008).

Fuel	Origin	Energy density MJkg-1	Energy production MJMJ-1fuel	Carbon ratio in the fuel kgCkg-1fuel	Carbon emission kgCO2MJ-1	Carbon emission during production KgCO2MJ-1	Carbon emission reduction KgCO2MJ-1
Low sulphur diesel	Crude	48.6	0.26	0.86	0.065	0.082	0.000
Diesel	Crude	48.6	0.20	0.86	0.065	0.078	0.000
Unleaded gasoline	Crude	51.6	0.19	0.86	0.061	0.072	0.000
Fuel oil	Crude	54.2	0.19	0.86	0.058	0.069	0.000
Anthracite	Coal	31.0	0.10	0.92	0.109	0.120	0.000
Methanol	Natural gas	22.4	0.20	0.51	0.083	0.100	0.000
Ethanol	Crude	35.0	0.20	0.52	0.050	0.070	0.000
Rapeseed oil	Oil seed rape	43.0	0.29	0.55	0.047	0.061	0.061
Biodiesel	Oil seed rape	43.7	0.44	0.61	0.051	0.074	0.074
	Recycled rapeseed oil		0.19	0.61	0.051	0.061	0.061
Methanol	Wood pyrolysis	25.0	1.00	0.51	0.075	0.150	0.150
Bioethanol	Wheat	35.0	0.46	0.52	0.054	0.080	0.080

	Maize		0.29			0.070	0.070
	Sugarcane/ beet		0.50			0.082	0.082
	Wood chips		0.57			0.086	0.086
	Straw		0.57			0.086	0.086
Charcoal	Wood	29.0	1.00	1.00	0.126	0.253	0.253

2.4. Acquisition method

Currently, there are three main sources of acquiring biofuel: Physical transformation, biochemical conversion, thermochemical conversion. Different methods have tremendous differences in technology, production cost and the end product.

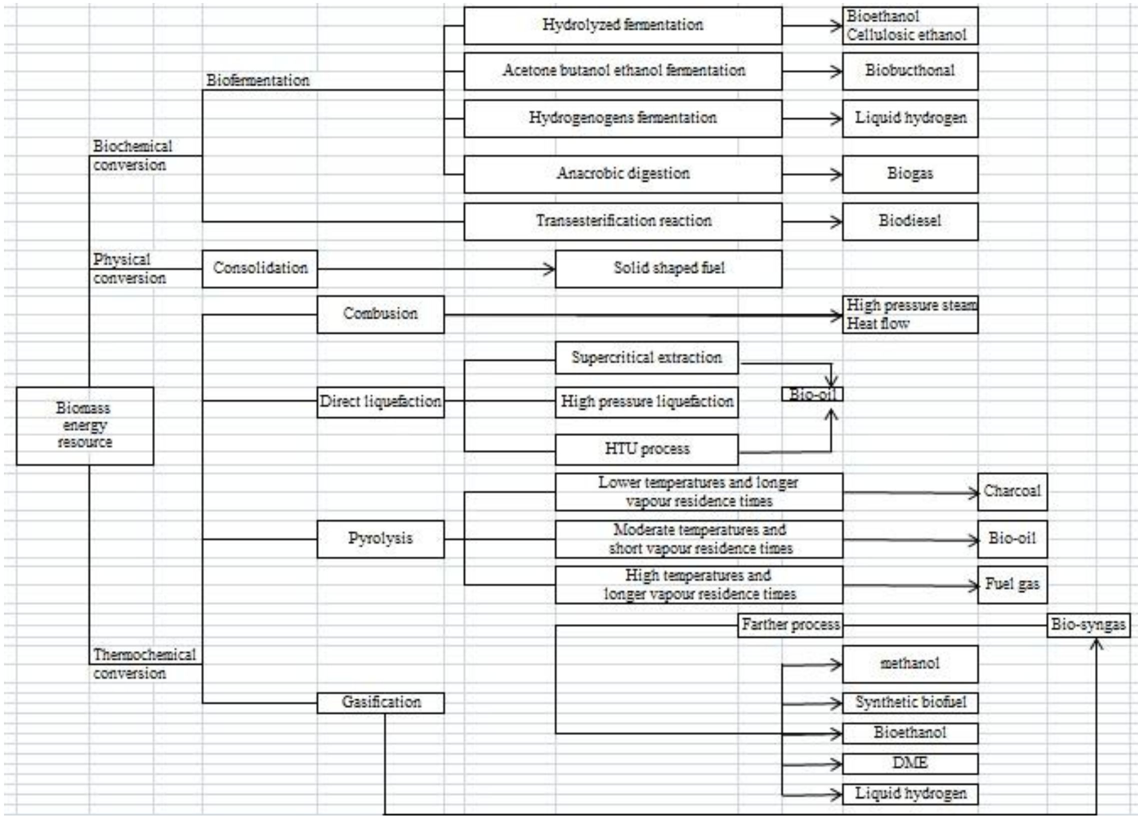


Figure 2-2 Three types of biofuels conversion processes and their relevant products obtained by different technology routes (Qin and Wang, 2009)

2.5. Development of biofuel

2.5.1 Zero generation biofuel: Hesitation era

The development of biofuel has a long history, and was already widely experimented and partly applied in the early internal combustion and automobile industry. In 1876, German engineer Nicholas Auguste Otto, the inventor of four-stroke internal combustion engine, has already attempted to use ethanol as a fuel; In 1892, inventor of the diesel machine Rudolf Diesel, has tried to use peanut oil as a driving fuel; In 1908 the first Ford model T was originally designed to run on ethanol (Zhao, 2004).

However, since the discovery of 1901 Texas oil field, the supply of global petrol has increased quickly, making petrol relatively cheap, and biofuel was eventually substituted by petrol and diesel. However, vegetable oil and bio-ethanol never left the combustion engine fuel market completely, and was developed in Brazil, Germany and USA in small scale. For example, in 1930s Brazil has used sugarcane to produce ethanol to fuel cars occasionally (Market Research of China Chuandong, 2009).

2.5.2. First generation biofuel: Food era

Since the 1970s, due to petrol resource, price of energy, environmental protection and global warming, many countries started to draw attention once again towards the biofuel market, with great success.

During this wave of biofuel development, ethanol and biodiesel received wide attention and development, and has made good progress in substituting petrol and diesel. As of 2006, the global production of ethanol and biodiesel were 39 billion tons and 6 billion tons.

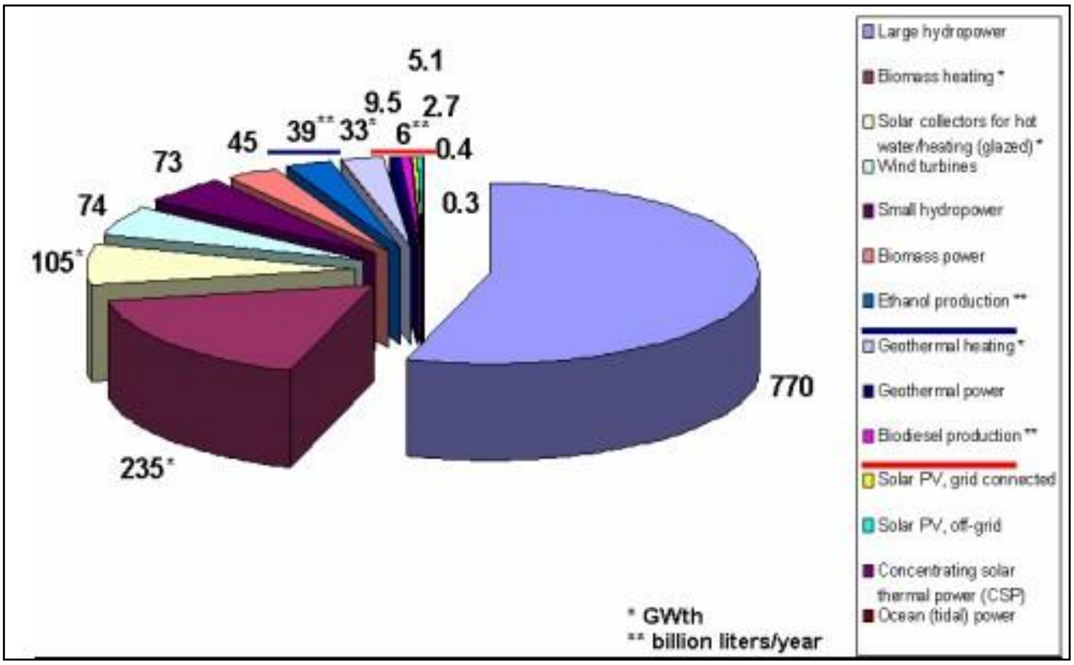


Figure 2-3 The global production of renewable energy (ethanol and biodiesel included) (2006) (Qin and Wang, 2009)

Within the industry many refers ethanol and biodiesel as first general biofuel, they generally used traditional technology (fermentation and oil extraction technology), using high-sugar crops, high-starch crops, oil crops or animal lipids as raw material. Ethanol's production mainly uses food as raw material, for example wheat and corn. Biodiesel uses oil crops as raw material, such as soy bean, rape seed oil, and olive oil and hemp seed oil.

Table 2-2: Major Nation's ethanol and biodiesel raw material status (Qin and Wang, 2009)

	USA	E.U.	Brazil	China	India	Malaysia	Canada
Bioethanol	Corn 98%	Wheat 48% Beet 29%	Sugar cane 100%	Corn 70% Wheat 30%	Sugar cane 100%		Corn 70% Wheat 30%
Biodiesel	Mainly soybean	Rape seed oil Mustard seed	Hemp seed oil	Waste oil, Cotton seed oil	Tung oil、 Cotton seed oil	Palm oil	Animal fat

2.5.3. Second generation biofuel: Era of cellulose

The common feature of first generation biofuel is that it takes away supply of human food, and is full of political controversy, not mentioning facing stagnation in raw material supply. According to research by American scientists, even if all of U.S.A's corn and soybean is used for biofuel production, it will only satisfy 12% of national demand for petrol and 6% of diesel; Developing non-food biofuel (2nd generation and 3rd generation) has become an important global issue, and is the direction of future biofuel (Pipi, 2010).

Second generation of biofuel applies to biofuel that are not produced through food such as corn, and is using straws, grass and timber, the agricultural waste as raw material, and uses biological conversion of cellulose as the method to produce biofuel, it mainly refers to cellulosic ethanol technology, Synthetic biofuel technology, biohydrogen technology, Bio-dimethyl ether technology, biological methanol technology, and biological dimethylformamide technology and various other technologies, among those, cellulosic ethanol and synthetic biofuel are the most important 2nd generation biofuel products (Chen and Yuan, 2011).

However, nowadays there is a high production cost for 2nd generation biofuel, among the technologies mentioned above, those that are commercialized are few, and are not in the same scale as fuel-ethanol and biodiesel. To increase the speed of 2nd generation biofuel development, U.S department of energy has announced a 44 million dollar investment to support the project led by six universities in development of biofuel (Xu, 2010). These projects are related to Microbiology, some even associated with genetic engineering, to increase the capacity of biofuel production, and lower the production cost.

2.5.4. Third generation biofuel: Era of microalgae

Third generation of biofuel refers to those which uses microalgae as raw material, and are also called microalgae fuel. Microalgae could be used to produce biofuels such as biodiesel, vegetable oil, bio-ethanol, bio-methanol, bio-butanol, and bio hydrogen. Microalgae can be cultured in ocean and waste-water; it will not pollute the water resource and have a significant lower impact on the environment.

Microalgae are a low-investment and high-production raw material, its unit production of energy per square meter is 30 times of soy bean. The US Department of Energy estimates, that if microalgae substitute all American petrol fuel, it would only need 15000 square miles, (38849 square kilometer), that area is around the same size as Maryland or 1.3 times of Belgium, and is 1/7 of American corn-production land usage (Qin and Wang, 2009).

The development of microalgae fuel started in 1978 by the Aquatic Species Program, led by the U.S Department of Energy, with its original purpose of focusing on bio hydrogen, in 1982 it shifted towards biodiesel and alcohol. University of Brooklyn, University of Ohio, University of Virginia, Montana State University and Arizona State University are all focusing on microalgae development. Besides America, Israel, E.U, Canada, Argentina, Australia and New-Zealand are all starting their own development of microalgae fuel.

3. Biofuels in China

China is the largest energy-consuming country worldwidely. Accompanied with the constant development of economic society, the requirements of China for energy is also constantly growing, which causes serious environmental issues. In addition, new energy has great significance to modern china society. With a new energy policy and advantages, it is a right time for China to develop biofuel. Nowadays, the Chinese Bioenergy industry maintains a positive development.

3.1. Current biofuel requirements

3.1.1. National economy development requirements

The liability to other countries concerning petroleum is gradually growing as well when imported original petroleum in 2009 was up to 204 million tons. The liability to other countries concerning petroleum is currently over 50% (Xu, 2010). Constant increasing requirements for original petroleum and constant increasing petroleum price is of severe harm to the energy security of China and the sustainable development of economic society. Therefore, the solution is to further decrease the consuming proportion of coal and petroleum by developing renewable energies including bioenergy, which could increase the utilizing ratio if energy in China, curtail the gap towards world advanced energy system, then further increase the supplying quality of Chinese energy and resources, and build a firm foundation of substances and resources for sustainably increasing economy.

The exhaustion of traditional energy forces the areas with abundant biomass resources to expect bioenergy to be a new economic increase point. Giant Companies like China Petrochemical Corporation (Sinopec), PetroChina Company Limited, China National Offshore Oil Corporation, and China National Cereals, Oils and Foodstuffs Corporation

(COFCO) all concentrate on bioenergy industry. COFCO holds controlling interests or shares the three fuel ethanol companies invested and constructed by the government by capital operation. National energy biological power generation corporations invested in multiple locations constructing straw power station. Sinopec and PetroChina also constructed bioenergy production enterprises respectively in Guangxi, Xinjiang, Hebei and Sichuan Province. Private enterprises act also actively concerning bioenergy when the number of private enterprises engaged in bioenergy exploitation is annually increasing as well.

3.1.2. Environment requirements

Environmental pollution is one of the most serious problems that China is currently confronting, which is also one of the biggest contradictions of restricting Chinese economy from increasing. Utilization of energy is the basic reason of environmental pollution. The energy discharging intensity could be largely decreased by developing bioenergy, adjusting and optimizing energy structure, which could also obtain more environmental discharging space for Chinese economy development.

Haze occurred in many parts in China, which rings the alarm for the environment. The formation of haze is much related to the discharging of energy wastes. As shown in Table 3-1, in the real-time ranking table of air pollution in 30 cities released at 21 o'clock on January 19th 2014, there are 12 heavily polluted cities with 24 cities reached seriously polluted level. Taking Beijing as an example (Figure 3-1), There are six important source of PM2.5 in Beijing, respectively, soil dust, coal, biomass burning, vehicle exhaust and waste incineration, industrial pollution and secondary inorganic aerosols, the average contribution of these sources were 15%, 18%, 12% , 4%, 25% and 26% (Zhao, 2013).

Table 3-1 In the real-time ranking table of air pollution in 30 cities (@Yak, 2014)

Air Pollution in China's cities							
Top	City	PM 2.5	Levels of Health Concern	Top	city	PM 2.5	Levels of Health Concern
1	Cangzhou	**469**	Hazardous	16	Nanjing	**282**	Very unhealthy
2	Hengshui	**447**	Hazardous	17	Wuhan	**277**	Very unhealthy
3	Jinan	**374**	Hazardous	18	Baoding	**275**	Very unhealthy
4	Tianjin	**357**	Hazardous	19	Changzhou	**270**	Very unhealthy
5	Tangshan	**341**	Hazardous	20	Qihuangdao	**259**	Very unhealthy
6	Lian Yungang	**332**	Hazardous	21	Jinhua	**278**	Very unhealthy
7	Hefei	**329**	Hazardous	22	Dalian	**257**	Very unhealthy
8	Yancheng	**328**	Hazardous	23	Henzhou	**250**	Very unhealthy
9	Taizhou	**322**	Hazardous	24	Qindao	**239**	Very unhealthy
10	Langfang	**320**	Hazardous	25	Handan	**237**	Very unhealthy
11	Huaian	**313**	Hazardous	26	Suzhou	**236**	Very unhealthy
12	Yangzhou	**308**	Hazardous	27	Zhujiang	**236**	Very unhealthy
13	Zhenjiang	**296**	Very unhealthy	28	Suqian	**232**	Very unhealthy
14	Xuzhou	**292**	Very unhealthy	29	Shaoxing	**232**	Very unhealthy
15	Huzhou	**282**	Very unhealthy	30	Nanchang	**223**	Very unhealthy

Figure 3-1 six important source of PM2.5 in Beijing (Zhao, 2013)

Fossil fuels are an important reason for these pollution. It is an urgent demand to improve fuel quality with a cleaner way. Utilizing renewable biofuel is an implementable solution. For example, the octane value of ethanol is 100, which contains congenital advantages; the octane value of petroleum is 84, which requires additives such as MTBE or ETBE to increase the octane value. Biofuel can adjust the structure of traffic fuels, increase fuel cleanness proportion, decrease the discharging of pollutants and greenhouse gases, which is the most realistic solution.

3.1.3. Rural society requirements

Rural areas are currently the weakest link of Chinese economy and the development of society, where energy infrastructure is underdeveloped, environmental sanitation is of poor condition, daily usage energy is normally made of straws and firewood burning, and clean energy supplement is to a large extent insufficient. Actively developing bioenergy industry and increasing clean energy supplement of rural areas could gradually change the underdeveloped way of utilizing energy for the thousands of years, which could increase rural energy utilizing ratio and improve rural sanitation condition and life standards of peasants.

As China is still in the process of industrialization and urbanization, biomass resources is still the major source of life sustaining and profit earning for peasants. which is a promising industry expanding agricultural functionality and improving resource utilization. For instance,crops straw solidification fuel testing program shall be started with barren mountains and fields usage and biomass material crops planting development encouraged.

Bioenergy industry development, which breaks through the traditional limitations, using agricultural products and their wastes to producing new energy, expanded the material usages and processing methods of agricultural products and provided a platform with enormous potentials and high product added value for agriculture, which also helps changing the ways of agricultural increase, developing recycling economy, expanding agricultural industrial chain, increasing agricultural profits, extending transmission space of rural extra labor force, which has deep influence on improving regional economy development and increasing peasants' incomes.

3.2. Current advantages of biofuel development

3.2.1. National policy and planning

Policy and planning plays an important even critical role in the developing process of the promotion of bioenergy industry. Chinese government attaches high importance to the policy and planning construction to promote the constant and stable development of bioenergy industry. Within recent years, Chinese government released in succession 'Renewable Energy Law', 'Catalog for the Guidance of the Industrial Development of Renewable Energy', 'The Interim Measures for the Administration of the Renewable Energy Development Special Fund', 'Opinions on Implementing the Development of Bioenergy and Biochemistry Fiscal Support Policy', as well as other accompanying laws, policies and regulations, which provides important legal protection for the development of bioenergy industry technologies in China and plays a critical role in promoting the rapid development of Chinese bioenergy industry.

The recently released sets of development plan in China is mainly concerning the technical development of bioenergy industry. Thereinto, a number of developing strategies and plans, such as, Outline of the National Program for Long- and Medium-Term Scientific and Technological Development (2006 - 2020) (Feb. 2006), The 11th Five-Year Plan for Energy Development (Apr. 2007), The 11th Five-Year Plan for Biological Industry (Apr. 2007), The Development Plan for Agricultural Biomass Energy Industry (2007 - 2015) (Jul. 2007), Long- and Medium-Term Program for Renewable Energy Development (Aug. 2007), and The 11th Five-Year Plan for

Renewable Energy (Mar. 2008), etc. propose explicit developing direction concerning the various domains of bioenergy. In addition, Long- and Medium-Term Program for Renewable Energy Development proposes clarified targets: In 2020 the utilized amount of biomass solid formed fuel shall be up to 50 million tons, annual utilized amount of methane shall be up to 44 billion square meters, annual utilized amount of fuel ethanol shall be up to 10 million tons, and that of biological diesel oil shall be up to 2 million tons.

3.2.2. Land resources

Land is one of the most important factor concerning the constant development of bioenergy industry especially biofuel. The 2008 Public Report of Land in China from Ministry of Land and Resources indicates farmland all over China is 1.218 million square kilometers, garden land 177 million mus, forest land 3.541 billion mus, pasture land 3.927 billion mus and other agricultural land 382 million mus.

Marginal land resources have been pinned great hopes. According to the investigation of The Collection of Renewable Energy Development Strategic Research in China - Biomass Energy Volume, the area of marginal land for potential biomass material production in China is up to 136.14 million hectares, which is equal to the area of farmland, among which backup land for agriculture is 7.34 million hectares, backup land for forestry is 57.04 hectares, marginal farmland is 20 million hectares, and marginal forestry land is 51.76 hectares. However, whether unused land could be transformed into bioenergy material depends on local climatic conditions, earth conditions, water conditions and eco-environmental factors. Unreasonable land reclamation usually does not pay off environmentally and economically, which results in the decrease of land amount being able to be transformed into energy plants land. Meanwhile, the distribution of marginal land in China is mostly in northwestern area, which is of contrary distribution to water resources and population. It brings great difficulty to actual exploitation. Because most of the unused land locates far with abominable natural condition and tremendous development costs, the future use of marginal land to produce bioenergy still left much to be done.

3.2.3. Energy plant resources

According to statistics, the number of plant types which could be valued as energy development plants is approximately 4000, which contains mainly Apocynaceae, Euphorbiaceae, Asclepiadaceae, Compositae, Myrtaceae and Leguminosae. Abundant utilization of marginal land such as saline and alkaline land, barren mountains and slopes, sand and so on, planting high-production and high-resistant energy plants, could provide tremendous amount of biomass materials and have positive impact on local ecosystem improvement. The main plants types that could be used are following:

Starch and Sugar Crops. Grain crops such as wheat, maize, and sorghum as well as tuber crops such as sweet potato and cassava are starch crops that are mainly used to produce ethanol. Current fuel ethanol in China are mainly made of maize and stale wheat. In mid-term and long-term future, non-grains such as potatoes, sweet sorghums and lignocellulose will be used to produce fuel ethanol.

Lipa Energy Plants. Lipa Plants include herbaceous plants and ligneous plants, the seeds of which are mainly used to extract oil from. Rapes, sunflowers, castor oil plants, and soybeans are the most important ephemeral lipa plants. China has abundant resources of oil plant seeds. The oil plant types which have been detected are up to 151 families, 697 genuses, and 1553 species, which takes up 5% of the total spermatophytes in China. On the other hand, the species number of oil plants distribute unevenly, and are differently locally distributed as well. The shrub species, which could be used to establish normalized biomass fuel oil material bases, are less than 30, among which the biomass fuels that distribute convergently, could be used as material bases, and could also use barren mountains and sand to build forestry to construct normalized seed supplement bases are only approximately 10.

Lignocellulose Plants. The main ingredient of lignocellulose plants is lignocellulose, which could directly burn and generate electricity, or be transformed into ethanol, syngas and hydrogen.

Energy Algae. Algae is a lower plant which distribute widely and is of great diversity. Algaes could provide lipa type, sugar type, and hydrocarbon type biomass materials, further producing bioenergies, such as biological diesel oil, alcohols, methane, hydrogen and so on. Oil-producing algaes have been focused recently, among which there are more than 10 types of algaes researched deeply.

3.2.4. Residue resources

Biomass energies include many other types of biomass residue resources.

Agricultural Residues. The agricultural organic residues production in China is ranking top of the world. Accompanied with the rapid development of agriculture and the increase of population, the organic residues also increase at the pace of 5% - 10%. So far, there are five utilizing methods of organic residues in China, including feed, fertilizer, energy, nutrition materials and multiple layers utilization. The organic residues used as poultry and livestock feeds include crop byproducts (e.g. straws, khfu), food processing residues such as rice husks, corn cobs, peanut husks, sugar canes and cottonseed husks, methane ferment residues and part of the poultry and livestock discharges, etc.

Forest Residue Resources. Forest residue resources indicate the energy provided during the process of forest growth and forest production, including firewood forest, scattered lumbers within forest cultivation and intermediate cutting, remaining branches, leaves and sawdusts; branches, sawdusts and wood dusts within the process of logging and processing; residues of forestry byproducts such as shells and kernels. Forestry biomass resources play an important role in Chinese rural energy.

Industrial Organic Liquid waste. Industrial organic liquid waste is the wasted water discharged during the production process of alcohol, brewing, sugaring, food, medicine, paper and butchery production. It contains abundant organics, which could produce methane with anaerobic fermentation process and produce hydrogen with fermentation in order to obtain energy.

The exploitation and utilization of biomass energy in China is still in the starting phase, which still requires further resource evaluation, suitable technology selection, multiple project demonstration, and related capability construction in multiple levels, especially under provincial level.

3.3. Current situation of the bioenergy industry

Currently, the development of Chinese biomass energy industry has been initially established, with certain experiences obtained; however, the maturity levels in different domains are to a large extent different. Minority of biomass energy transformation and utilization technology has been applied as industrialization, such as, rural domestic using methane, farm methane engineering and straw power generation technology. Biomass power generation, biomass densified formed fuel, and biomass liquid fuel have entered the early phase of commercialization with many newly born biomass energy technologies still in researching phase.

3.3.1. Gas fuel

The Methane industry in China started in the 1970s. Experienced two major falls and three rises, the industry is currently in the third rising period. Till the year 2007, the increase number of rural methane users in China was up to 4.8235 million with national collective promoting user methane tanks of 26.5 million, which is 18.02 million more than that of 2000, and annual methane production of 10.2 billion cubic meters with a annual increase rate of 17.7%. 26.6 thousand farm methane projects have been constructed, with total capacity of 2.85 million cubic meters and annual methane production of 0.356 billion cubic meters (Huang, 2008). Meanwhile, concerning composite utilization, using methane as media, efficient agricultural production pattern of biomass multiple-leveled utilization and energy rational streaming has been constructed. The “4 in 1” methane ecological agriculture pattern promoted in northern area and the “P-M-F” pattern which is the modern agricultural technology using breeding industry as leading, methane as linking, driving the development of agricultural products and commercial crops, and the ecological agriculture pattern of multiple layered composite utilization of methane, biogas slurry, and biogas residues, have been the new increasing point in rural economy, as well as the specialties of Chinese biomass energy utilization.

The domestic used methane technology in China has been leading in the worldwide ranking; however, the medium and large sized methane engineering projects is late in development, where there has been huge gaps concerning diversity of material types, methane fermentation techniques of different materials, researches on microbial inoculums, instruments and equipment technologies of formalized methane engineering, methane fermentation products and composite utilization of solid remaining residues, compared to developed countries, which requires further original innovation.

3.3.2. Solid formed fuel

According to the difference in processing craftworks, solid formed fuels could be divided into screw extrusion, piston stamping, mould pressing, roller pressing and so on. Concerning different engine types, it could also be divided into mechanical drive and hydraulic drive technical types. In China, screw extrusion type pressing forming technology is prevailing and wide promoted. A deep research has been done by Henan Agriculture University and Hefei Tianyan Green Energy Exploitation Co.Ltd. concerning the abrasion performance of extruding screws, which extended the operating lives (Dong et al., 2007). Currently, the production and application of biomass solid formation machines in China has formed initially certain scales, and has entered gradually semi-commercialization and commercialization phase. However, there is still considerable gap towards international leading standards (Meng et al., 2008).

3.3.3. Biomass liquid fuel

The development of Chinese biological liquid fuel also made impressive progress, especially in the biological diesel oil production and the fuel alcohol production in production using grains, which has been already formed into certain scales.

3.3.3.1. Biodiesel

Great importance has been attached to biological diesel oil by not only Chinese government but also research departments and corporations. During the period of the eighth and ninth “Five-Year” plan, researches on collection of wild oil materials - wilsoniana oil, esterification changing characteristics, and application testing were launched. Within the period of the tenth “Five-Year” plan, ministry of Sciences and Technology has listed the exploitation of wild oil materials and biological diesel oil technology development into national “863” plan and relevant National Key Technologies R&D Program. The research work was launched in research departments like Chinese Academy of Sciences, Jiangsu Institute of Petrochemical Technology, Beijing University of Petrochemistry, Jilin Agriculture Academy of Sciences, and Guangzhou Energy Research Laboratory, and so on with great success in biological diesel oil production with colza oil, soybean oil and wasted deep frying oil as materials. Special departments were established also in giant state-operated corporations, such as China Petrochemical Corporation, PetroChina Company Limited, China National Offshore Oil Corporation, and China National Cereals, Oils and Foodstuffs Corporation. Additionally, privately operated companies of biological diesel oil production appeared as well in China, developing biological diesel oil production technology and industrialized demonstrating factories of proprietary intellectual property rights. According to the incomplete statistics of biological diesel oil project group of Guangzhou Energy Research Laboratory, current number of biological diesel oil producing companies in China has been up to 69, with a production capability of 1.1363 million tons/year (Yang, 2009).

To sum up, biological diesel oil industrialized production in China has been formed in certain scale, but using craftworks were mostly original innovated. Concerning the limitation of the research time and research standard level of the companies, most of the technologies of Chinese biological diesel oil companies are still in the starting phase, with weak environmental friendliness and economic competence, low industrialization and commercialization level, which requires further development.

3.3.3.2. Biofuel ethanol

Currently, the production technology of ethanol fuel in China has reached a high level of maturity, as ethanol gasoline for motor vehicles has been used as substitute of regular unleaded gasoline in many provinces, such as, Heilongjiang, Jilin, Liaoning, Henan, Anhui, and most part of other provinces, such as Hubei, Hebei, Shandong, Jiangsu. Ethanol gasoline has taken up 20% of national total gasoline sale amount. China has become the third largest biological fuel ethanol producing and applying country after Brazil and the USA (Wu et al., 2007).

The technology to realize industrialization for fuel ethanol is producing ethanol using starchiness (corns, sweet potatoes, cassava, etc.) and sugariness (sugarcanes, beets, sweet sorghum, etc.) During the period of the tenth “Five-Year” plan, four biological fuel ethanol production testing projects were established in Heilongjiang, Jilin, Henan, Anhui, four provinces in China, with an annual production of 1.02 million tons, using mainly stale grains that saved as grain reserves for long. In order to expand biomass fuel sources, fuel ethanol production technology using stalks of sugar sorghums and cellulose wastes as materials has been originally developed in China.

Biological fuel ethanol industry development is still in the starting phase in China, which still requires further positive planning and promotion in various aspects. On the other hand, many existing problems, such as material limitation, weak foundation of technology industrialization, weak marketing competence of products, and incompleteness in policies and market environment, shall be dealt with (Li, 2008).

4. Biofuels handling system

4.1. Storage of biomass

If there is a time interval between production and application, it is necessary to store biomass fuel for a long time to balance consumption and production.

Stacking is the most simple way of storing biomass. Usually wheel-type loaders are used to transport fuel. There are several factors requiring attention paid to (Loo and Koppejan, 2008): Firstly, when long-term storing wood flour and rinds with over 30% moisture proportion, under certain conditions, the heat produced by biomass degradation and biological degradation could possibly result in self-ignition. Second factor will be the loss of dry matter, changes in moisture proportion and health issue (the growth of fungi and bacteria). The reaction mentioned above is to some extents complicated, which is decided by mainly the size of materials (whole trees, big wood brick, wood flour and saw dust), moisture proportion, storage methods (outdoors, outdoors with covers and indoors), and ventilation methods (sealed storage, non-ventilation and compulsory ventilation).

Short-term biomass storage instruments and the feedstock entrance of ignition or pretreatment system are directly connected. Concerning short-term storing loose materials (wood rinds and saw dust), the feedstock could be done using sliding rod transmission machines (or movable floors). The structure of sliding rod transmission machines (Figure 4-1) is firm, which is suitable for wood rinds and flour storage; Movable floor is to move material as a whole, which suits automatic material unloading without extra instruments. However, the defect is that the feedstock will have to start from the top because of the stacking height (Figure 4-2); When moving fuel from long-term storing room into warehouse, wheel-type loaders shall be used (or cranes).

According to the materials used and unloading technologies, stacking height could be up to 10m with warehouse intersecting surface 10m $\times$25m, and unit volume of material warehouse up to 2500m^3 (Marutzky and Seeger, 1999).

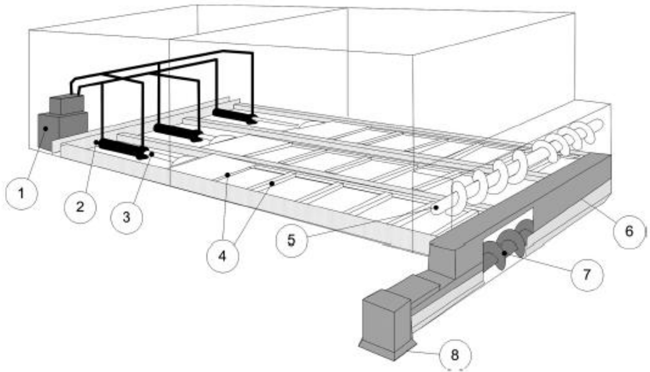


Figure 4-1 Sliding bar conveyor used for the discharge of bunkers (Loo and Koppejan, 2008)

Explanations: 1=hydraulic generator, 2=bearing for hydraulic cylinder, 3=hydraulic cylinder, 4=sliding bars, 5=control screw, 6=drop conveyor, 8=delivery end

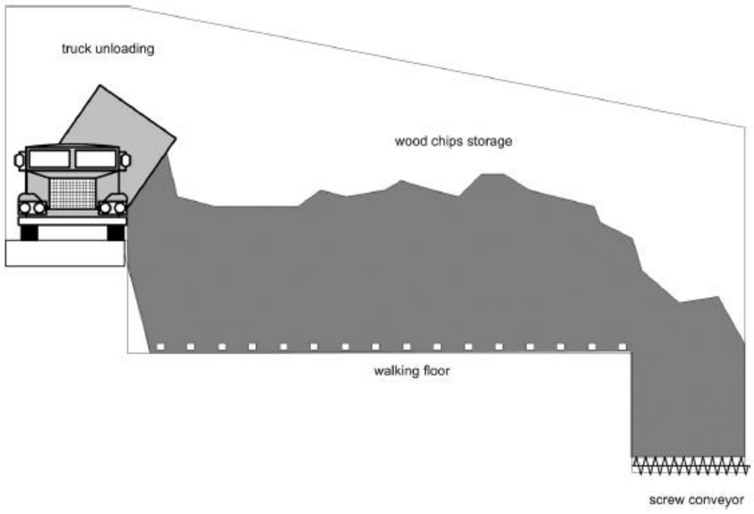


Figure 4-2 Walking floor used for the discharge of biomass fuels from a long-term storage hall (Loo and Koppejan, 2008)

In order to avoid dust raising, saw dust and waste lumber granule shall be stored in sealed silos. The diameter of the silo could be up to 15m with height 40m (Marutzky and Seeger, 1999). Silo uses horizontal screw transmission machine with mixer to unload materials automatically (Figure 4-3). When the fuel is stored in feed bin or silo, the bridging phenomena of material shall be taken into account. The correct design of feed bin and unloading system could avoid the bridging phenomena.

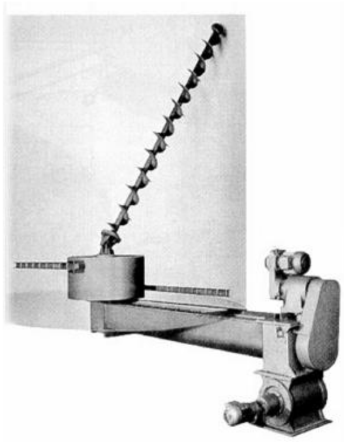


Figure 4-3 Inclined rotating screw used for the discharge of silos (Marutzky and Seeger, 1999)

4.2. Fuel-feeding and handling systems

Fuel Transmission from providing spot (or storage position) towards combustion or pretreatment system requires feeding and handling system. The variety of biomass fuel requires as well suitable feeding and handling systems. The following factors shall be considered when they being operated: fuel characteristics (granule shape, size distribution, and moisture), transmission distance, height difference, noise, ingredient explosion and fire avoidance, transmission amount, practicability of feeding system and handling maintenance costs (Marutzky and Seeger, 1999).

Wheel-type loaders (see Figure 4-4) provides the simplest and most flexible feeding method, which is nearly suitable for various loose materials (saw dust, wood rinds and waste lumbers). The volume of scraper pan is over $5m^3$, which however, requires manual operation (Loo and Koppejan, 2008). It is not allowed in fully-automatic system and meanwhile costly.

Cranes are suitable for the cases transmitting grass bunches, wood flour and granule fuel from storage position into feeding instruments (Figure 4-5), which could be operated automatically. However, it is not suitable for the cases when granule fuel is of uneven shapes, such as, wood rinds, saw dusts, and wood flour mixture.

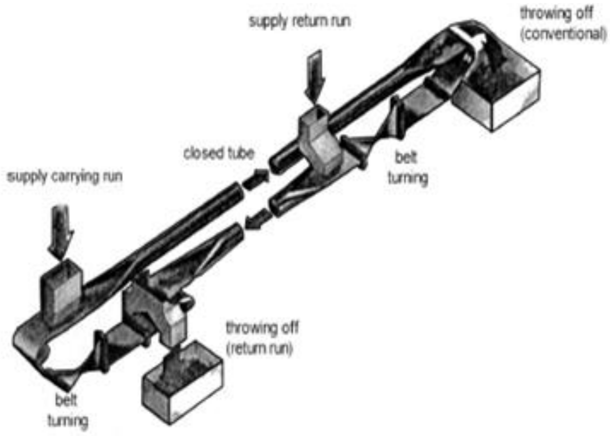
Figure 4-4 Wheel-type loaders (Loo and Koppejan, 2008)

Figure 4-5 Automatic crane for straw feeding (Nikolaison, 1998)

Belt-type conveyors are constructed with two or more circle belts of guiding wheels, which are usually used in long distance fuel transmission. It suits the transmission of loose or singular material. The characteristics include simple structure, low cost and belt weigh meter installation. However, belt-type conveyer is not suitable for tilted location with meanwhile high cost of maintenance. Moreover, it is prone to be effected by the environment.

Tube-rubber belt conveyor is a sealed instrument, avoiding nurturance phenomena (Figure 4-6). It convey materials bi-directionally, with curved conveying belt, which avoids the height difference. However, it is not suitable for long or sharp materials. Tubular belt conveyer could accomplish transmission with distance over 2000m (Loo and Koppejan, 2008).

Chain conveyor (Figure 4-7) is suitable for transmitting materials such as saw dust, wood flour and wood rinds. It could also load and unload material at any location. The conveyer shall be fully sealed in case of dust raising. The disadvantages are high power output, low transmission amount, and severe abrasion of chains and slots.



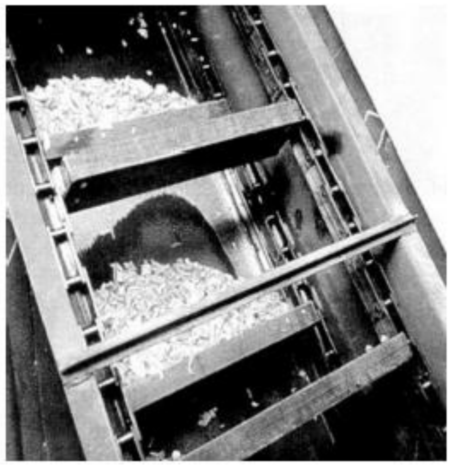


Figure 4-6 Tube-rubber belt conveyor

(Loo and Koppejan, 2008)

Figure 4-7 Chain trough conveyor

(Loo and Koppejan, 2008)

Auger-type conveyer is suitable for loose material transmission without dusts and powders (Figure 4-8). The advantages are low geographical occupation and low price. It is suitable for short-distance transmission of biomass fuel with granularity lower than 50mm, but not for wood rinds (Loo and Koppejan, 2008). Meanwhile, the capacity of auger-type conveyer is relevantly high. In addition, the metal and mineral impurities within could result in machine breakdown.

Hydraulic piston feeding machine is suitable for bundled materials (e.g. straws and grains), as well as loose materials of uneven granularity.

Bucket elevator could transmit materials of medium or small granularity acclivitously or vertically (Figure 4-9) with transmission capacity of 400t/h, and maximum transmission height 40m (Pajer and Kuhnt, 1988). The granularity of material is decided by the size of the bucket. Elevating small granule with high speed could result in dust raising.

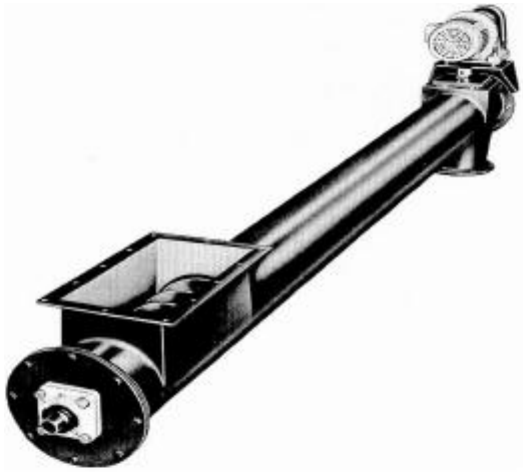


Figure 4-8 Screw conveyor

(Marutzky and Seeger, 1999)

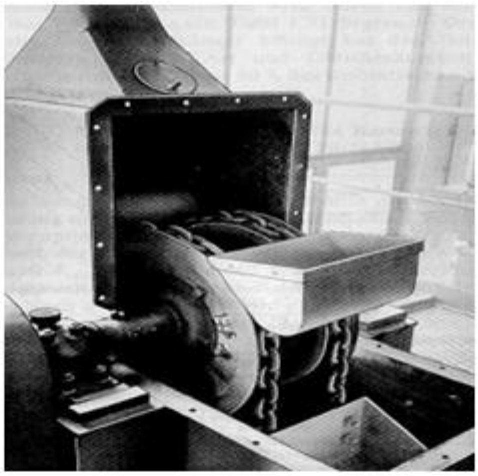


Figure 4-9 Bucket elevator

(Pajer and Kuhnt, 1988)

4.3. Biofuels transport systems

As the energy density of biomass fuel is even lower than that of fossil fuel, biofuel transmission shall confront higher transmission cost. Hence, the transmission distance shall be minimized in order to reduce the cost, which to some extents results in the requirements of biofuel distributional application. Moreover, the utilization capability of different transportation tools shall be optimized. All transportation tools could apply, which however depends on transmission distance and the types of biofuel.

Tractors with trailers are usually used in unchipped thinning residues, forestry wood flour and various types of herbaceous biofuel.

Trucks could be used in long-distance transmission of various woody biofuels (e.g. logs, unchipped thinning residues such as bulk or bundles, woodchips, sawdust and bark) and herbaceous biofuel. The type difference of trucks is determined by the transmission types of biofuel. For the transportation of logs, flatbed trucks with side stakes are commonly used when bulk materials like woodchips are usually transported in trucks with side walls and a tilting bed; Pellets can also be transported by such tipper trucks, with special tank trucks used instead (Loo and Koppejan, 2008).

Rail transport is used for logs, bundles and industrial by-products in bulk form with different wagons available depending on the fuel to be transported; the transport of herbaceous biomass fuels by train is of minor relevance (Loo and Koppejan, 2008).

Transportation of biomass fuels by ship could be reasonable for long distances and large-scale biomass trade; and it is especially relevant for the transportation of pellets, because pellets have become an internationally traded product currently (Loo and Koppejan, 2008). However, not only pellets, but also woodchips and bales or bundles could be transported by ship.

4.4. Biofuels pretreatment systems

Biomass energy technology is the technology transforming biomass into energy and making it utilized. According to the characteristics of biomass and transformation types, biomass energy technology could be divided into solid fuel production technology, liquid fuel production technology, gas fuel production technology. Biological liquid fuel could replace gasoline as transportation fuel, which could not only solve the energy security problem, but also contribute to the reduction of greenhouse gas discharge. It could also be used as fundamental organic chemical resource, representing the future direction of biological fuel. Liquid biofuel includes fuel ethanol, bio-diesel, and biological fuel oil BTL gasified or liquefied from biomass and chemically synthesized; Gas biofuel include methane, biomass gasification, biomass hydrogen production technology, with industrially producing methane and methane purification as transportation fuel, GTL, which is also the recent feasible technology for developing gas biological fuel (Xia, 2011).

This paper is introducing pretreatment biofuel technology using natural biomass as resources. Biomass pretreatment is the treatment technology used for satisfying the specific requirements of certain craftwork towards biomass, which is also an optimization treatment for natural biomass. Via the pretreatment, some characteristics of natural biomass could be changed, such as hardness, graininess, density, and some chemical characteristics etc (Yi et al., 2005). Because of the diversity and multi-formation of biomass, and the differences in certain characteristics, different treatment craftwork has different requirements towards biomass resources. Hence, the biomass pretreatment technology is of great complexity.

4.4.1. Solid biofuel pretreatment

The production process of biomass energy has formed an interrelated and interdependent chain (including fuel supplying, energy transformation, energy utilization, and discharge treatment and recycling, etc.). Within this chain, the purpose of “fuel supply” is to produce fuel from various biomass resources (see Figure 4-10). Biomass solid fuel is mainly used in combustion. For example: illustrates various paths for wood fuels from the forest to the end-user (Figure 4-11).

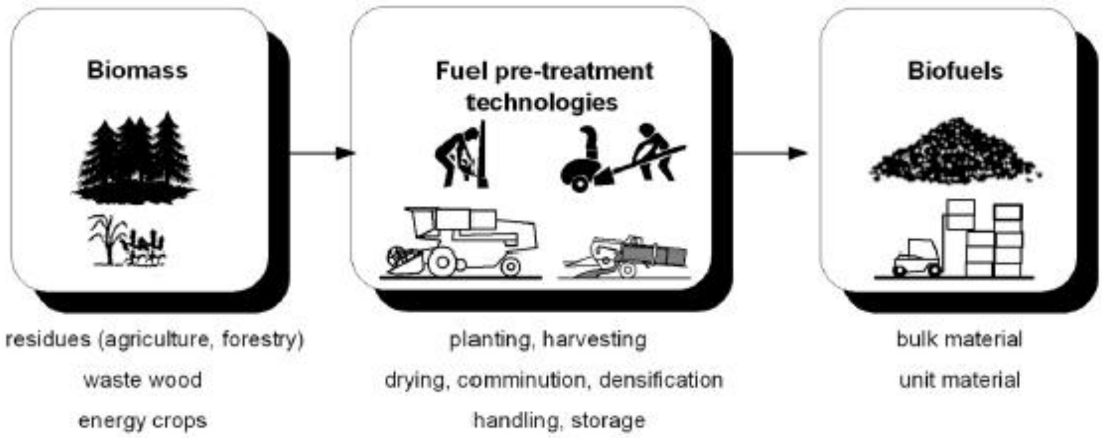


Figure 4-10 Fuel supply chain for woody biomass (Loo and Koppejan, 2008)

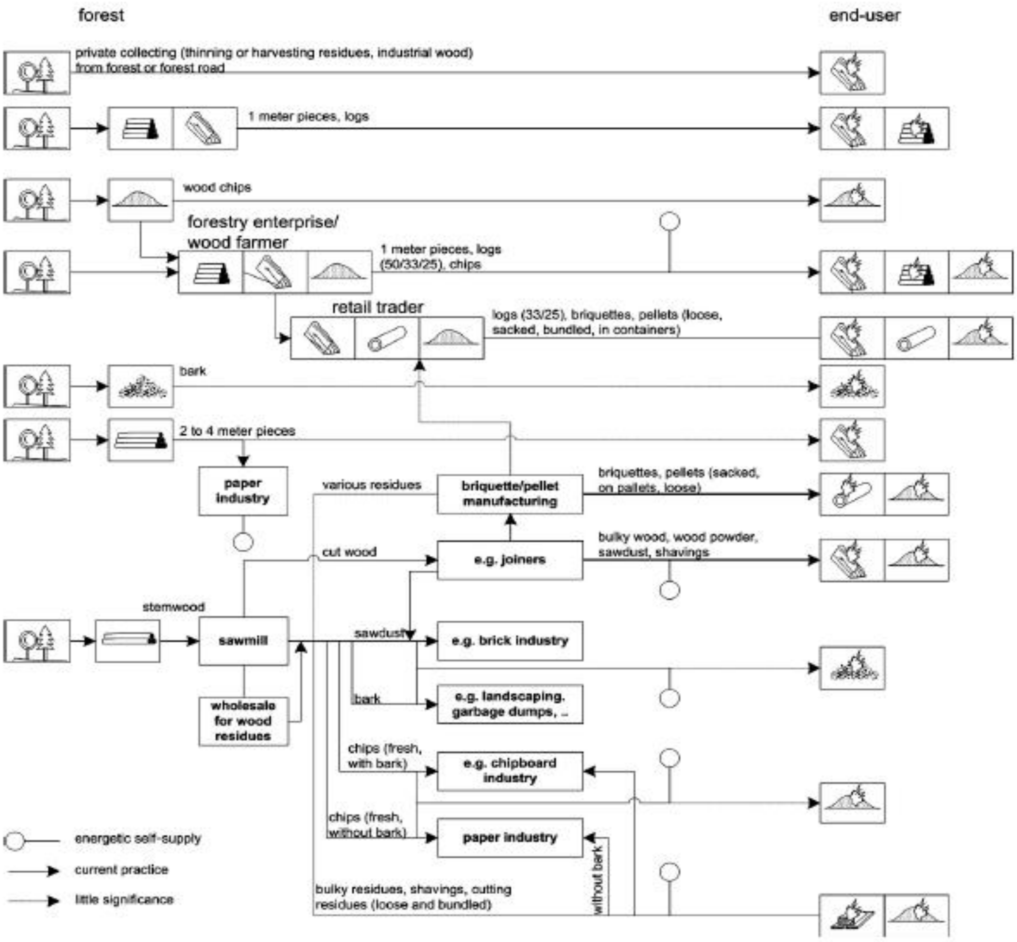


Figure 4-11 Wood fuel flows from the forest to the end-user (Loo and Koppejan, 2008)

According to different craftwork processes, solid biomass pretreatment technology could be divided into desiccation technology, excision technology, comminution technology, granulation technology, and solidification technology. Using straw as examples, the pretreatment for straws is described as follows:

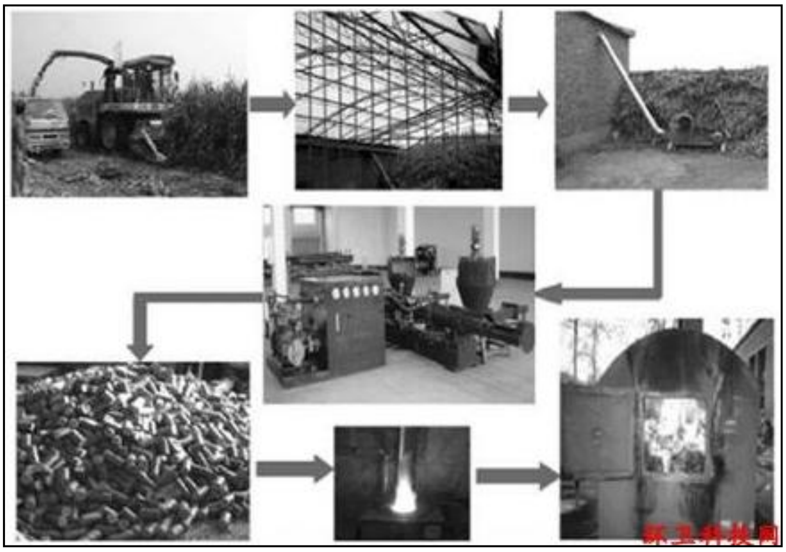


Figure 4-12 Cycle processes of straw from collected, desiccation, comminution, Molding and firing (Li et al., 2010)

Desiccation Technology: Desiccation is the process of vaporizing the water in the resources and obtaining solidified products using thermal energy, which is, simply put, the process of water vaporization by heating wet resources. In terms of biomass desiccation, we have to options: natural desiccation and artificial desiccation, which is drying machine desiccation. Natural desiccation has nearly no extra requirements when artificial desiccation requires a decent control on desiccating temperature.

Excision Technology: Biomass straw excision technology is to change the geometrical size of straw by using the straw excising instrument named cutting machine. Soft straw cutting machine is usually called ensilage cutter, or chopper mill, which could handle maize straw, wheat straw, haulm, millet straw, cotton straw, tobacco straw, and etc. Excision Technology is mainly aiming to change the geometric size of straws, at the same time enlarging the density of straws and enhancing the flowability, the changes of which has advantages towards biomass straw utilization.

Comminution Technology: Comminution is the process of solid resources comminuting from big lumps into small lumps under the effects of external forces. After resources comminuted, the superficial area increases with mixture more even, meanwhile with granularity decreased and easy for transportation and storage. There are various types of comminution machines, some of which has requirements concerning the size of resources and moisture content. There are limited number of comminution machine types that are suitable for straw comminution, which are normally hammer-type comminution machines. Currently, the major problems for comminution machines in market are the weak balance of rotors, high density of dust, high ambient noise, and so on. After straw being comminuted, its geometrical shape is changed with density increased and flowability increased as well, which are advantageous for the application of biomass straws.

Granulation technology: Granulation technology is the technology compressing exiguous and lightweight resources into granule with machines or instruments. As straw has low density with also a big shrinkage ratio, with external forces applied onto straws, under the effects of water and cellulose, straw could be produced into granules. Generally speaking, the chemical characteristics before and after the granulation are nearly unchanged; however the density of resources changes dramatically. The density of granulated straw is between 1.0 and 1.5 g/cm3, with relevantly regulated geometric shapes of to some extent identical granule shape and size, with also increased density and weakened ignitability. The factors that influence straw granulation mainly are types of resources, moisture ratio, the size, shape and the ‘heating-or-not’ of granulation machine models. Currently, the problem of Chinese granulation instruments is mostly short service life, as rotatable parts, cutting blades and sifters are prone to be broken, which will result in debris mixed with end products.

Molding technology: In the recent years, the exploitation and application of biomass molding technology is quite rapidly developed. Vast research has been done in Chinese

Academy of Forestry, Liaoning Academy of Energy, Henan University of Agriculture, and so on, with technologies of great maturity. Straw molding is the technology of compressing straw into certain shapes, which could increase the density. The molded straw usually has large size. During the process of molding, the tremendous friction force between straw and molding sleeves generated huge amount of heat, which normally results in the carbonization process of straw. Resource Characteristics, granularity, flowability, rate of water content, and temperature are the direct factors that influencing the biomass molding quality. The resources with high lignin content, small granularity and weak flowability are more moldable, with the impact of water content rate and temperature towards resource molding could be seen in Table 4-1 and Table 4-2 (Yi et al., 2005).

Table 4-1 Resource water content rate influence towards Molding (Yi et al., 2005)

WCR (%)	4	6	8	10	12	14
Wood Flour	Non-Moldable	Moldable	Moldable	Moldable	Moldable	Non-Moldable
Straw	Non-Moldable	Moldable	Moldable	Moldable	Non-Moldable	Non-Moldable

Table 4-2 Temperature impact towards Molding (Yi et al., 2005)

Temperature (℃)	180	200	220	240	260	280
Wood Flour	Non-Moldable	Non-Moldable	Slow Molding	Fast Molding	Very Fast Molding	Very Fast Molding
Straw	Non-Moldable	Non-Moldable	Fast Molding	Very Fast Molding	Very Fast Molding	Severe Carbonization on Surface

4.4.2. Liquid biofuel pretreatment

Based on the long and mid-term development planning and targets of many countries worldwide towards biological liquid fuel, it could be seen that governments address high hope upon the second generation liquid fuel, leading to the supplement and substitution of transportation energy and decrease of greenhouse gas discharges.

Producing bio-ethanol and bio-diesel resources will expand from grain and pea to lignocellulose, so that, the complete contented biomass could be utilized fully, which is the so-called 'Second Generation Liquid Biofuel' – lignocellulose ethanol and synthetized biodiesel (Wu and Liu, 2008). Lignocellulose is one of the most economic and widely existing resources in the world, as the main component of all green plants, which was estimated to be up to 150 billion tons with huge amount of biomass energy (Su and Cheng, 2010).

Biomass pretreatment technology is most widely used in the process of cellulose zymolysis producing ethanol; therefore, the development of biomass pretreatment technology in this domain is wide as well (Liu et al., 2014). Currently, the main craftwork of cellulose fuel ethanol is pretreated biomass fermented with yeast producing ethanol via cellulose enzyme hydrolysis:

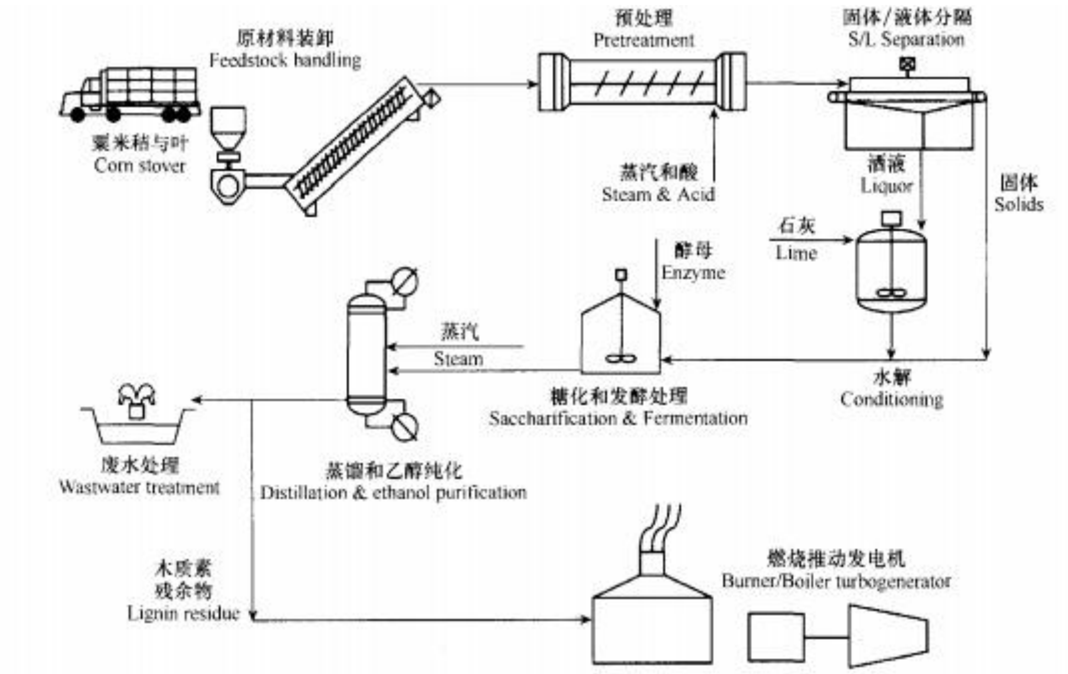


Figure 4-13 Simple cellulosic ethanol process flow diagram (Liu and Wu, 2008)

Generally speaking, the pretreatment must fulfill the following conditions (Liu and Shen, 2005): Increasing the binding rate of enzyme hydrolysis; Avoiding the degradation and loss of carbohydrates; Avoiding producing side-products restraining enzyme hydrolysis; High cost performance. The pretreatment methods include physical method, chemical method, physical-chemical method, and biological method.

4.4.2.1. Physical pretreatment

Physical pretreatment includes mechanical milling, squeezing, and radiation.

Mechanical milling could decrease the size of biomass granule, changing the super-micro structure of lignocellulose, decreasing crystallinity, in order to increase the cellulose zymolysis efficiency. The disadvantage of mechanical milling is the huge energy cost and the incapability of removing lignin (Hendriks and Zeeman, 2009).

Squeezing is the process of changing the physical and chemical characteristics of materials by heating, mixing, and cutting in a squeezing machine. The zymolysis efficiency of material after being squeezed is determined by the spinning speed of squeezing machine screw and charging barrel temperature (Karunanithy et al., 2008).

Radiation include microwave and ultrasonic wave. Microwave radiation could change the super-micro structure of cellulose, eliminating lignin and semicellulose, in order to increase the cellulose zymolysis efficiency (Wang et al., 2013). Ultrasonic treatment has limited impact on cellulose ultra-microstructure, meanwhile decreasing the surface area and detrimental towards following zymolysis (Zhao et al., 2007). The advantages of ultrasonic treatment are the high thermal efficiency, easy handling, when the disadvantages are high investment cost and detriment to industrialization.

Generally speaking, the major advantages of physical treatment is the low pollution rate to environment and easy process. However, the requirements of high energy and motive power will therefore increase the cost to some extents.

4.4.2.2. Chemical pretreatment

Chemical Pretreatment includes acid treatment, alkaline treatment, ozone treatment, organic solution treatment and ionic liquid treatment.

Acid treatment is aiming to dissolve the semicellulose, especially xylan, in biomass, in order to obtain catabolites, such as xylose, seminose, acetic acid, galactose and glucose, as well as limited amount of glucose biodegraded from cellulose and phenolic compound biodegraded from lignin.

Alkaline treatment is the biomass treatment using alkaline solutions, such as, NaOH, KOH, Ca(OH)2, and ammonia water (Taherzadeh and Karimi, 2008), which are used to remove lignin and partially semicellulose, largely increasing the cellulose zymolysis efficiency. Under the same circumstances, compared to other treatment method, the effect of alkaline treatment in removing lignin is much better, and much easier in cutting the ester bond of lignin, cellulose, and semicellulose (Silverstein et al., 2007; Gaspar et al., 2007). Compared to timber-like biomass, alkaline solution is also better for treatment of agricultural straw biomass. Different alkaline solution treatment for biomass will generate different biomass waste structures. Furthermore, based on the special characteristics of different alkaline solutions, the following work of treatment will differ dramatically as well.

Ozone treatment is to remove the lignin in biomass, accompanied with the degradation of semicellulose with most of cellulose sustained. Ozone is a strong oxidizer, which could dissolve biomass in two different ways. First one is the direct reaction of ozone of molecular states with biomass. And the second is the dissolving reaction with free radicals, which are generated from the process of ozone degradation biomass (Contreras, 2002). The advantages of ozone treatment include high efficiency of lignin removal, no impact on following zymolysis by degradation products, and reaction under normal atmospheric temperature. The disadvantage is also the high cost in industrialized application (Palmqvist and Hahn-Hagerdal, 2000).

Organic solution treatment is the process of treating biomass by using various organic solutions, such as alcohol, acid and ketone within the temperature limitation of 100 - 250 ℃, with or without catalytic agent added (Zhao et al., 2009). After biomass being organically treated, most of the lignin and semicellulose could be removed with nearly all cellulose sustained. The advantages of organic solution treatment are the easy retrieval of organic solution and the high purity of lignin. The disadvantages are the waste of water and time due to the requirement of washing solid waste after organic solution treatment, high retrieving cost. Organic solution treatment also requires to be done in complete obturation, in case of divulgence and security accidents (Zhao et al., 2009; Aziz and Sarkanen, 1989).

Ionic Liquid Treatment uses the organic positive ions and inorganic negative ions which exist in liquid form under relevantly low temperature (normally ordinary temperature). Ion liquid is of chemical stability and thermal stability and is also nonflammable. It exist in the form of liquid under low steam pressure and low temperature. Different ion liquid has different effects of reacting on lignocellulose. The biggest advantage of adopting ion liquid treatment is that all components will be fully sustained without being dissolved. And the disadvantage is high cost, and huge detriment towards following zymolysis (Alvira et al., 2010).

4.4.2.3. Physical-Chemical Pretreatment

Physical-chemical pretreatment method includes hot liquid water treatment, steam explosion treatment, ammonia fiber explosion treatment, CO2 explosion treatment and wet oxygen treatment.

Hot liquid water treatment is to treat biomass under the condition of water saturation tension, when keeping water in the form of liquid under the temperature of 160 – 240 ℃ (Alvira et al., 2010; Wang et al., 1999). After the biomass treated via hot liquid water, almost all semicellulose and par of the lignin has been removed, with all cellulose sustained. The advantage of hot liquid water treatment is that no other additives shall be put in during the whole process other than water, which is environmentally protective, non-corrosive to instruments, of low density of inhibitor production, and not detrimental to following zymolysis. The disadvantage is that water requirement is high, with high energy cost and detriment to industrialized production as well (Alvira et al., 2010; Wang et al., 1999).

Steam explosion treatment is the process to use compressed steam treating biomass for several seconds or minutes and reducing pressure in a sudden, resulting in a sudden change into steam of inner water in biomass, which could break the structure of lignocellulose, degrade semicellulose and lignin, and dissolve cellulose. Steam explosion treatment could be used for various biomass, including hard wood, soft wood, agricultural straws, which is a pretreatment of high efficiency. The advantage of steam explosion treatment is that all parts of biomass could be completely retrieved, with better energy saving outlook and low cost (Avellar and Glasser, 1998). The disadvantage is that the degradation products of semicellulose will have detrimental effects on following zymolysis and fermentation (Alvira et al., 2010). To improve the impact of steam explosion treatment, some researchers found that after merging biomass into acid solution, alkaline solution or organic solution for a while under mild condition (normally ordinary temperature), the explosion effect is much better than that of regular water steam explosion, which make it easy for cellulose zymolysis (Zabihi et al., 2010; Ma et al., 2003).

Ammonia fiber explosion treatment is to merge biomass in ammonia water for a while under the pressure of 0.7 – 2.8 MPa, and temperature of 70 - 200 ℃, and then decrease

pressure in a sudden, which turns the ammonia water that penetrates into biomass into steam, which results in inflation of lignocellulose, damaging the structure of lignocellulose, decreasing the crystallinity, and making cellulose easier to be hydrolyzed by cellulose (Alvira et al., 2010; Bals et al., 2010). This treatment could remove lignin or change the structure of lignin, meanwhile sustaining complete semicellulose and cellulose (Taherzadeh and Karimi, 2008). Ammonia fiber explosion could dispose agricultural straws and herbaceous crops efficiently, but has limited effects on biomass containing high lignin.The advantages of this treatment include decreased crystallinity of cellulose, damage to the link of lignin, cellulose and semicellulose, increasing the number of micropores on cytoderms and pore diameters, ammonia retrieval, limited inhibitors, no requirements for water cleansing for solid wastes, and no requirements for adjusting pH value of solid wastes (Alvira et al., 2010; Laureano-Perez et al., 2005). The disadvantage is the high cost of ammonia and its retrieval (Mosier et al., 2005).
CO2 explosion treatment is similar to steam explosion treatment, with the difference in using supercritical CO2. Supercritical CO2 has the density of liquid and diffusivity of gas, with low surface tension, which is easy to penetrate into biomass containing micropores. When the pressure decreased suddenly, inflation results in vaporization, damaging the biomass structure and increasing zymolysis efficiency. The advantages include the low cost and high security of supercritical CO2 and low temperature requirements (Kim and Hong, 2001). The disadvantages are the high cost of high-tension equipment and the limited types of biomass that could be disposed efficiently (Narayanaswamy et al., 2011).

Wet oxygen treatment is the process of disposing the biomass merging in water within certain period of time, with temperature over 120℃, and using oxygen or air as pressurizing gas (Taherzadeh and Karimi, 2008; Martin et al., 2007). The main factors influencing the effects of the treatment are temperature, time and oxygen pressure (Taherzadeh and Karimi, 2008).The advantages are mainly limited production of small molecular weight inhibitor and high efficiency in lignin removal. The disadvantage is the high cost of oxygen, which is detrimental to industrialized production (Alvira et al., 2010).

4.4.2.4. Biological treatment

Biological treatment is the pretreatment method using microbes or the enzyme produced by microbes to degrade lignocellulose. Actinomyces, bacteria, and fungi could degrade lignocellulose by producing lignocellulose degradation enzyme such ass, cellulase, hemicellulase, and ligninperoxidase. As Actinomyces and bacteria producing cellulase and hemicellulase, especially the low activated lignin degradation enzyme. That results in the long process of lignocellulose degradation, which is usually used in compost treatment (Malherbe and Cloete, 2002; Trigo and Ball, 1994). Compared to xylophyta, they are more suitable to herbage degradation. Hence, fungi is mostly used in biological pretreatment. Due to the use of microorganisms or biological pretreatment of lignocellulose enzymes, processing conditions are relatively mild, so the biological pretreatment of biomass with low cost, low energy consumption and environmental protection, etc., but its biggest drawback is the long processing time, not suitable for industrialization application (Kumar et al., 2008).

For easy comparison, different treatment methods are listed in the following table.

Table 4-3 Different treatment methods

Methods	Features and advantages	Disadvantages
Mechanical Milling Squeezing Radiation	+ Low environmental impact; + Processes simply	- High power and energy; - High cost
Alkaline Treatment	+ Efficiently increase zymolysis characteristics; + Efficiently dissolve lignin	- Corrosive; - Pollution
Ozone Treatment	+ Efficiently dissolve lignin; + No toxic material produced;	- Huge quantity of ozone required - High cost

	+ Could be done under ordinary temperature	
Organic Solution Treatment	+ Efficiently dissolve lignin;	- High temperature required; - Pollution
Ionic Liquid Treatment	+ Effective at solvating cellulose; + Minimal environmental impact	- High cost; - Induction of cellulose inactivation; - Effective regeneration; - Causticity and toxicity of ILs; - Selection of stable ILs
Hot Liquid Water Treatment	+ Low cost; + Less inhibition; + Low corrosion; + Less residues; + High simplicity	- High temperature; - Particle size reduction required to obtain high yield
Steam Explosion Treatment	+ Mature research; + Low energy cost; + Good environmental benefits	- Part of xylan is damaged; - Cannot completely break the stroma of lignin-carbohydrate; - Produce inhibitor of microbes
Ammonia Fiber Explosion Treatment	+ Low enzyme requirement; + Minimized degradation products; + High solids loadings	- Formation of oligomeric form of hemicelluloses degradation products
CO2 Explosion Treatment	+ Economic edge compared to steam explosion and ammonia explosion; + Efficiently increase zymolysis characteristics	- Low saccharde production; - High operation pressure
Wet Oxygen Treatment	+ Efficiently remove lignin; + Obtain cellulose of high purity; + Limited side products	- High cost - High operation pressure
Biological Treatment	+ Low cost; + Low energy consumption; + Environmental protection	- Long processing time; - Not suitable for industrialization application

4.5. Case study about fuel ethanol production

Hereby we select a case of fiber fuel ethanol production using corn straws. The experimental product line of fiber fuel ethanol production using corn straws is technically supported by the reproducible energy experimental spot of the agriculture department in Jiangsu, financially supported by Suzhou Nongye Shiye Ltd. Corporation. This project experimental product line was constructed in May 2008, and went officially into operation in June 2009. Corn straw materials are mainly from Wuzhong Region and Xiangcheng Region that are close to the factory. The collection work was done by local specially constructed straw collection station. This work is prone to decrease the potential risk of the massive storage of corn straw materials, with transmission collection radius of 10km. After the natural air-drying, the moisture proportion of corn straws is usually 11%±1%, with retrieval price 235 RMB¥/t. Grinded into 60 - 80 mesh, with the price of grinding and transporting 70 – 80 RMB¥/t, corn straws will then be transmitted to the material storage unit in the factory. The main ingredients were measured as following table:

Table 4-4 Main components of Corn Straw

Ingredient	**Mass Proportion/%**
Cellulose	36.8
Semicellulose	25.9
Lignin	17.6
Ash Content	2.1
Leachable	16.6
Dust	1.0
Total	100

Based on the operation process of 350t/a experimental product line, examined from aspects including technical standards, economic standards and environmental standards, the evaluation system of straw fiber ethanol was described as Table 4-5. Based on the table, unit cost of ethanol production within the process of fiber ethanol production using corn straws was researched on, as well as individual proportion within ethanol production cost.

Table 4-5 Production evaluation system of corn straw cellulosic ethanol

Coefficient	**Category**	**Unit**
Technical Standards	Saccharifying Rate	%
	Ethanol Mass Concentration	g/L
	Ethanol Production Rate	%
Economic Standards	Water Cost	t/t
	Energy Cost	kJ/t
Environmental Standards	CO_2 Discharge	t/t

Dilute acid pretreatment technology is adopted in this experimental project product line, combined with sugar synchronous fermentation technology. The craftwork flow is described in Figure 4-14.

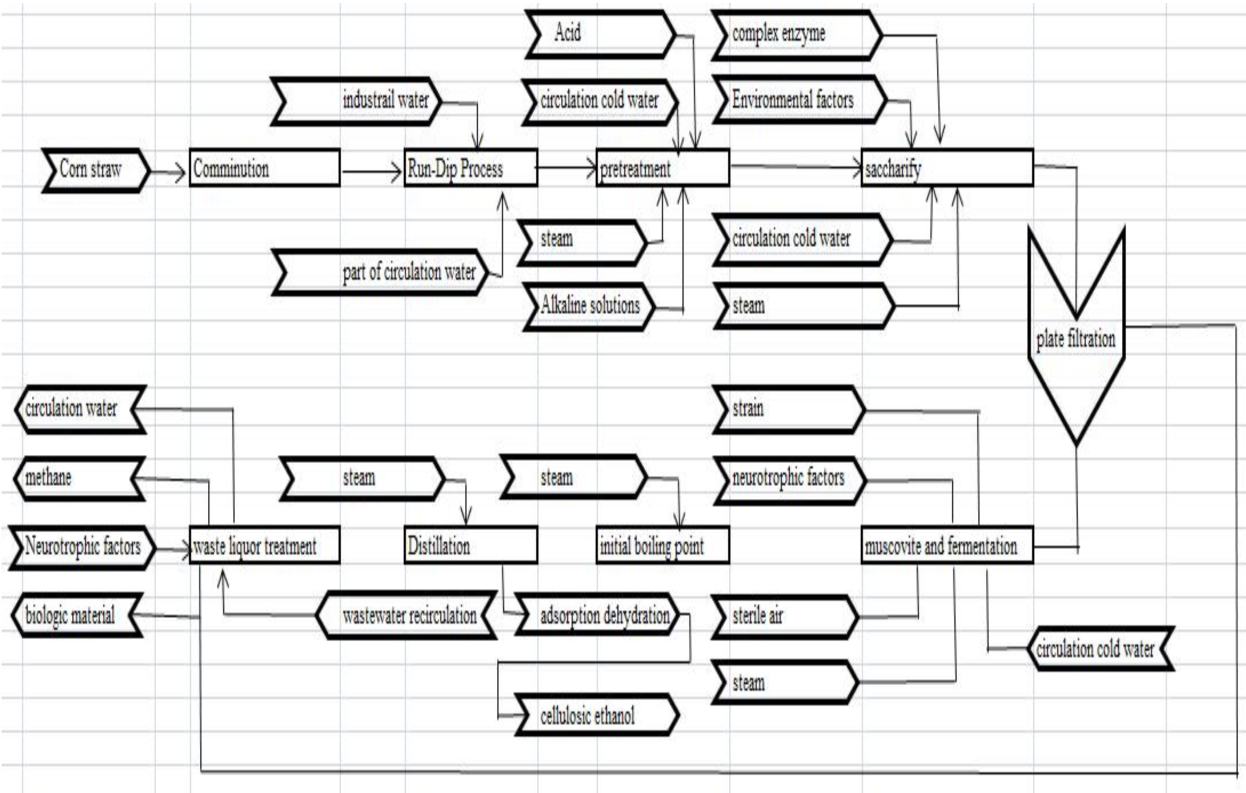


Figure 4-14 Process flow of cellulosic ethanol demonstration plant

Within the production process research, this part will focus on fiber ethanol production technology craftwork, based on the production process of experimental production factory, where three system categories were built described as Table 4-6.

Table 4-6 Results of key indicators for corn straw cellulosic ethanol production

Coefficient	**Category**	**Unit**
Technical Standards	Saccharifying Rate (%)	52.2
	Ethanol Mass Concentration (g/L)	23.4
	Ethanol Production Rate (%)	18.7
Economic Standards	Water Cost (t)	11.9
	Energy Cost (kJ/t)	3.07×10^7
Environmental Standards	CO_2 Discharge (t)	3.8

According to Table 4-6, corn straws dilute acid pretreatment technology producing fiber fuel ethanol achieved relevantly better results, with ethanol mass concentration up to 23.4g/L, ethanol production rate 18.7%, and water cost 11.9t/t, which is relevantly low. It is because within the production process, steam cooling water and distillation tower cooling water, as well as the slot solution separated from ethanol distillation, could be cyclically utilized after natural sedimentation and adjustment treatment. Within the production process, unit ethanol energy cost, compared to starch-based material, the former is approximately 2.5 times of the later, the difference of which is because of the two procedures of pretreatment phase and distillation phase. Within the process of pretreatment, because of the density characteristic of straws, solid liquid ratio is 5.8 – 7.0, compared to the same ratio of state ethanol company corn solution 3.5 – 3.7 (Wu, Zhao and Li, 2003). The higher the solid liquid ratio is, the higher is the energy cost. On the other hand, within the distillation process, the ethanol mass concentration of the fermented liquid is 2.3 – 2.5g/L, comparing to the fermented liquid ethanol volume proportion of other state large ethanol companies 12% - 14% (Wu, Zhao and Li, 2003).

Therefore, the remarkable difference in this two aspects increased the unit ethanol production energy cost. The CO_2 produced within the process is mainly from coal consumption and cell metabolism of fermentation process, the ratio of which is approximately 3.2. Concerning the CO_2 within the production process, recycling technology has been invented accordingly. It is used in the production of full-degradable plastics, which reduces 33% of CO_2 discharge, and at the same time helps decreasing the production cost of fiber ethanol.

This case was selected as it is an experimental platform of fiber ethanol production using corn straws, with key technical standards considered. The result shows that at the experiment product line, the saccharifying rate of fiber ethanol reaches 52.2% with ethanol mass concentration 23.4g/L, ethanol production rate up to 18.7%, energy cost 3.07×10^7kJ/t and water cost 11.9t/t.

Ethanol production technology is not yet completely mature, which is still in the phase of transition. Firstly, cellulase cost is still high. On the other hand, unit energy cost of production is far greater than the energy cost of corn fuel ethanol. Therefore, these two are the bottlenecks of influencing and restraining the industrialization of it. However, the research on fiber ethanol production experiment is the essential factor of future industrialization, is also the important foundation of its engineering technology. Accompanied with the breakthrough and completion of key technologies, the production cost of fiber ethanol is still prone to be decreased sharply, which also provided practical foundation and technical support for the future development. It will continuously promote the commercialization development of fiber ethanol technology.

So far, China is standing in the phase of energy industrial structure transformation and upgrading. Therefore, development of reproducible energy will contribute to the sustainable development strategy of circular economy in China.

5. Biofuel use in transportation focus on China

5.1. Characteristics of transportation energy in China

China is still currently in the early phase of transportation development, with a personal automobile retention per capita less than 10%. In the recent 10 years, the increasing rate of automobile has been up to 20%, when in 2010 the total consumption of automobile used gasoline and diesel was over 0.13 billion tons; Since the Reform and Open, aviation industry has been growing at a rate of 17.5% as well with an annual consumption of aviation fuel over 20 million tons; Shipping fuel consumption is also increasing sharply; Meanwhile, gasoline consumption in transportation domain has taken up over half of the total gasoline consumption; IEA, OPEC, and EIA predicted that by 2030 gasoline liquid fuel consumption in China will be up to 0.75 – 0.83 billion tons (Kang et al. 2012). In 2011, the dependence degree on import oil of China was over 55%, with annual increase of 2% - 3%; Based on the prediction of IEA, this could become 76.9% by 2020 (Kang et al. 2012). The problem of national energy security has been increasingly serious.

Thus, the fuel mainly used in Chinese transportation industry is diesel oil, where 39 million tons of gasoline (equals to 14 billion gallons) are annually spent, as well as 91 million tons of diesel oil (equals to 28 billion gallons), 1.5 million tons of ethanol (500 million gallons), and 600 thousand tons of bio-diesel oil (0.2 billion gallons); Diesel oil and gasoline are still the main transportation fuel in China, which taking up 96% of the total consumption amount of energy (Accenture, 2011). Compared to that, compressed natural gas and other replaceable energy (such as bioenergy) takes up only less than 4% of the total transportation energy consumption (Accenture, 2011). Figure 5-1 shows the current energy structure of China.

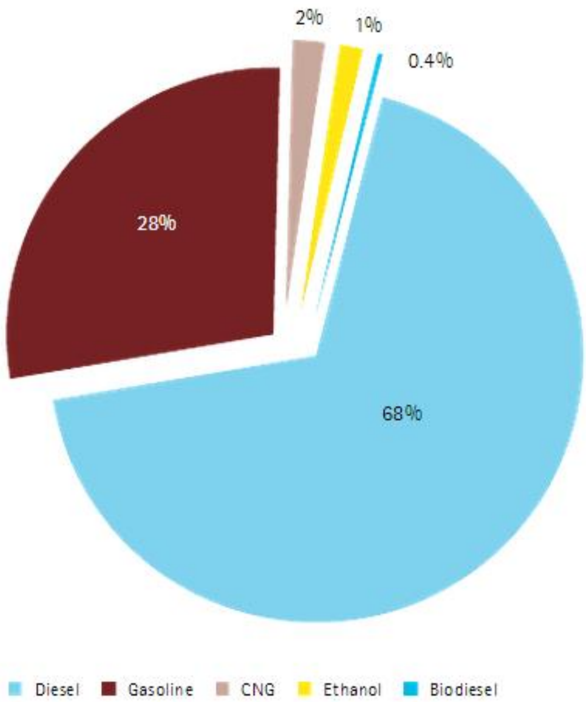


Figure 5-1 Transportation Fuel Structure of China (2009) (Accenture, 2011)

5.2. Application of biofuel in transportation domain

In order to weaken the dependence on gasoline and contribute to the reinforced decarbonization effort of transportation industry, bioenergy provides a transition method towards low carbon and non-gasoline fuel, which requires only limited changes to current automobiles and allocation infrastructure. Despite of the fact that increasing the efficiency of automobiles is the most efficient way so far to decrease the discharge of carbondioxide in transportation industry, bioenergy still is demanded to play a more important role in replacing liquid fossil fuel suitably used in aeroplanes, oceanic vessels, and other heavy transportation models that could not be electrified. The production and utilization of bioenergy could also bring benefits, such as, increase of energy security, by decreasing the dependence on gasoline import and the undulating of gasoline prices (OECD/IEA, 2011). Within the recent years, Chinese government is increasing rapidly the investment on on replacable energy. Until the year 2009, the investment amount of replacable energy in China has been up to 240 billion RMB Yuan (35 billion US

Dollars), which is more than that of any other country (Factive, 2010). In order to realize the target of replacing hydrocarbon fuel with replacable energy to decrease the greenhouse gas discharging by 40% in China by the year 2020 (based on the discharging level of 2005), Chinese government is planning to invest five trillion RMB Yuan more (740 billion US Dollars) (Factive, 2010).

Transportation energy requires urgently replacement and supplement when biological liquid fuel is considered as the future of transportation replacement energy. According to the report of Biological Liquid Fuel Technology issued by IEA in 2011, 27% of the global transportation fuel will be biofuel by the year 2050 (IEA, 2011). Biological liquid fuel is also one of the only feasible way of biomass energy utilization replacing gasoline-based fuel, which will boost the application of this technology route with extraordinary significance. Considering the fact that biomass is a reproducible biological source carrier, biological liquid fuel can directly replace fossil fuel, which is impossible for other new energy carrier to achieve.

Currently, bioenergy is mainly used in highway transportation and aviation. There are mainly two kinds of bioenergy replacing highway transportation oil types, that is, fuel ethanol and biological diesel oil. Biofuel is generated from agricultural products, forestry, agricultural and forestry wastes and energy plants. The manufacturing technologies are of varieties and different from resource to resource. Biofuel is often utilized by mixing with automobile-using gasoline and diesel oil, which makes the automobile-using mixture fuel have clear advantages in environmental protection and oil substitution profits than pure gasoline and diesel oil (Zhuang and Jiang, 2007). The development of biofuel technology provides huge potentials to aviation industry, when currently, many aviation companies has been testing aviation biofuel in practice. The fuel that aeroplanes using is produced using animal, plant and algae oil as resources with hydrogenation technology.Seen for the long term, searching for biological aviational fuel for massive application in business exploitation has become the urgent requirement for global aviation business, which accelerates the cooperation of members of the aviation industrial chains including aeroplane manufacturers, aviation companies and engine production companies, and the leaders of acadamic domain of energy, to exert utmost in developing aviation biofuel for civilian use and achieve the environmental protecting aviation and sustainable development.

5.3. Fuel ethanol in transportation

In the year 2001, it was decided to add fuel ethanol into automobile-using gasoline. Meanwhile, the State Bureau of Quality and Technical Supervision issued two national standards concerning "Transitional Fuel Ethanol" and "Automobile-using Ethanol Gasoline". The country invested over five billion RMB Yuan allowing to construct four fuel ethanol enterprises which target on consuming old store, with a total productive capability of one million tons (Dan, 2006). In the year 2006, fuel ethanol productive capability of China was up to 1.63 million tons. The testing use of automobile-using fuel ethanol gasoline E10 (90% gasoline and 10% fuel ethanol) was promoted into nine provinces as well as 27 local cities, with the sale amount of fuel ethanol gasoline up to 10 million tons, which also took up 20% of the total sale amount of gasoline in China. In China, fuel ethanol was promoted in a mode of "Fixed-locational Production and Closed Sales", taking Zhongliang Zhaodong Ethanol, Henan Tianguan, Anhui Fengyuan Biochemistry, Jilin Fuel Ethanol, Zhongliang (Guangxi) Bioenergy as the five designated ethanol production enterprises, meanwhile CNPC and SinoPac as main fuel gasoline distribution saling system. On April 15th 2008, in Guangxi province, the first area where non-grain fuel was used to produce fuel ethanol, fuel ethanol gasoline was fully authorized to used with regular gasoline forbid to sale. In 2009, the sales amount of fuel ethanol was approximately 1.73 million tons, among which non-grain fuel ethanol production 200 thousand tons, with ethanol gasoline taking up 20% of national gasoline sales amount. In 2011, the number of Chinese fuel ethanol sales amount went up to 1.9376 million ton, which ranked third in the world. However, fuel ethanol automobiles were still in the phase of local promotion and utilization. Till 2020, the annual production of fuel ethanol in China will be up to 10 million tons, with a proportion of automobile using E10 fuel up to 100% (Zhuang and Jiang, 2007).

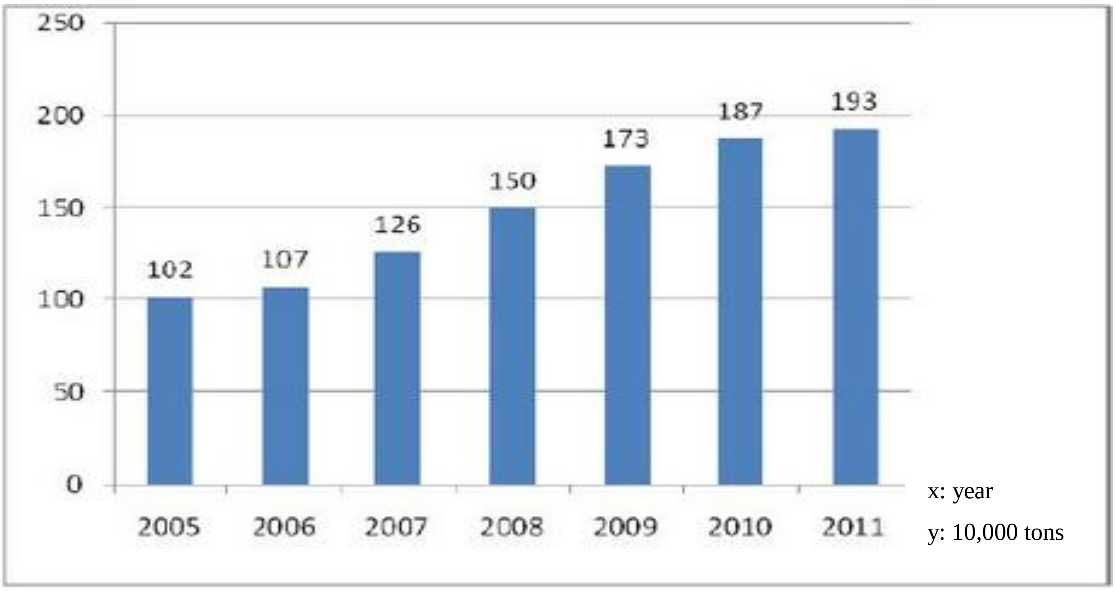


Figure 5-2 Fuel ethanol production amount of China 2005 – 2011 (Glinfo, 2012)

From now to the year 2015, sweet sorghum and potatos are the main resource of ethanol in China, with annual production up to five million tons. From 2016 to 2025, fuel ethanol production focuses on sweet sorghums, potatoes and lignocellulose both when woody oleiferous plants. After 2025, lignocellulose, as the second generation biofuel, will be contributing to the additional production capability of fuel ethanol. Ever since the demonstration and promotion of ethanol gasoline, China has been providing full support to fuel ethanol production with financial supporting policies of subsidy and preferential taxation. because of the resource supply and national policy, China has become the third biggest fuel ethanol production country.

Table 5-1 The fuel ethanol production statistics in each continent and country in 2011 (Glinfo, 2012)

Continent 大陆	Millions of Gallons 百万加仑
North & Central America 北美和中美洲	14,401.34
South America 南美洲	5,771.90
Europe 欧洲	1,167.64
Asia 亚洲	889.7
Africa 非洲	38.31
USA 美国	13,900.00
Brazil 巴西	5,573.24
China 中国	645.9
Canada 加拿大	462.3
Australia 澳大利亚	87.2

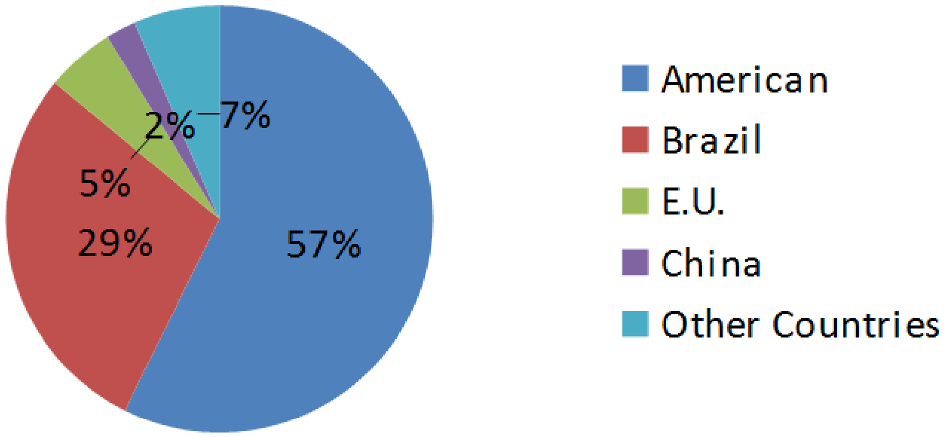


Figure 5-3. Global Ethanol Annual Production Proportion in 2013

Table 5-2 Fuel Ethanol Situation 2012 – 2014 (10 thousand cubic meters / year)

Country	2012	2013	Estimated 2014
America	5040	5000	5200
Brazil		2500	2590
EU	450	450	520
China	210	200	200
Global Output	8360	8720	9160

Seen from the newest and predictive data, annual production of fuel ethanol has been increasing annually, with the USA and Brazil leading in the world. In 2013, the production of these two countries took up 86% of the total global production amount, among which the annual prodcution amount of the USA was twice of the sum of Brazil, China and EU. As the third largest fuel ethanol production country, China took up only 2.3% of the global amount. Meanwhile, from 2012 to 2013, the prodcution of fuel ethanol is decreasing instead of increasing. In sum, as a new born industry, in China, fuel ethanol industry is still in a unstable phase, concerning not only technology but also resource supply and national policy changes.

5.4. Biological diesel oil (Bio-diesel) in transportation

Currently, biological diesel oil has been mainly used in transportation industry, shipping business and other domains that contain high possibility of causing environmental pollution (such as mining). The importance of biological diesel oil has been globally recognized with a number of research and experiment underway. Demonstration and promotion of biological diesel oil has been put into practice in over 100 cities, using over 1000 buses with several million kilometers drving distance. From now to the year 2015, illegal cooking oil, sediments and cottonseed oil are the main resource for bio-diesel with annual production up to one million tons. From 2016 to 2025, winter-idle-field vegatable seed oil are used as the main resource of bio-diesel. After 2025, lignocellulose, as the second generation biofuel, will be contributing to the additional production capability of bio-diesel.

As bio-diesel is able to be mixed with fossil diesel by any possible proportion, it has been widely used in diesel engines. Researches have been performed in many researching institutions, such as, Beijing Institute of Technology, China University of Petroleum, Jiangsu University, Tsinghua University and Chinese Research Acadamy of Environmental Science, concerning bio-diesel engines and driving experiments. Not only has bio-diesel been used in diesel engines, but also it has been used in automobiles as well. When mixing with 20% bio-diesel into gasoline or original diesel oil used as automobile fuel, comparing with utilization of pure gasoline and diesel, particulate discharge will be decreased by 14%, oxycarbide by 13% and carbondioxide by over 70% (Li, 2013). In China, the first automobile using cortex jatropha bio-diesel was demonstrated in Yunnan. In the early August of 2007, 1000 buses in Beijing were added bio-diesel, which was expected to decrease the discharge of end gas by over 95%. In 2006, China designated a medium-term and long-term developing target for biological diesel oil production, that is, up to two million tons by 2020. In the recent years, the production scale in Hainan, Fujian, Sichuan, Anhui and Shandong has been up to two or three million tons; however, the actual annual production amount was less than 100 thousand, which resulted in severe overcapacity. The main reasons for the situation include insufficient supply of resources, lack of product standards and promotion plans for automobile-using biological diesel oil, causing the sluggishness of production sales, which also conducted the application of biofuel towards agricultural dynamic machines and chemistry products (Kang et al. 2010). At the end of 2010, General Administration of Quality Supervision Inspection and Quarantine of the People's Republic of China and Standardization Administration of the People's Republic of China issued the standard for biological diesel oil and fuel (B5) and implemented on February 1st 2011, indicating that as legal fuel of automobiles, biological diesel fuel has been officially accepted into the end-production oil sale system.

In China, aviation biofuel has made periodic progress in experiments. On November 28th 2011, AirChina 747 airliner accomplished the first testing flight with biofuel, landing successfully on Beijing Capital Airport, which indicated the success of first application of aviation biofuel in passenger aeroplanes in China. The testing flight result showed that biomass fuel could save fuel consumption up to 1.2% adn reduce the discharge of carbondioxide by 60% - 75%. Meanwhile, aviation biofuel completely satisfies the flight height requirements of large-scale passenger aeroplanes, acceleration performance and engine restarting (Hubei Daily, 2013). Within the aviation fuel used in this testing flight, traditional aviation fuel was mixed with aviation biofuel by 50 – 50, with the aviation turbine fuels and aviation biofuel were both from CNPC. This was the 13th testing flight worldwide, and also the only testing flight with resources planting, oil extraction and processing, and testing evaluation proceeding in the same country. On April 24th 2013, China Eastern Airline airliner 320 was successfully tested with aviation biofuel extracted from illegal cooking oil, which represented the landmark success in research of aviation biofuel in China, which at the same time made China one of the several countries obtaining the technology of self-research and exploitation. It has been a trend with aeroplane-using biofuel replacing aviation coal and gasoline, said Yinxiang Wang, Vice President of Airchina. By the year 2020, aviation biofuel will be expected to take up 15% of the total aviation fuel. In addition, by 2050, it could be also expected to reduce the discharge of carbon in global aviation business by half by massively using biofuel (Hubei Daily, 2013).

However, the development of clean diesel automobile in China has always been facing the problem of diesel intermittent shortage, low quality, and low acceptance level of customers. Thereinto, as the so called "green fuel", bio-diesel has not been policy-promoted smoothly resulting in the lagging behind comparing to other developed countries. Meanwhile, bio-diesel has not been accepted in the regular gas station selling process in China. Bio-diesel could be used replacing regular diesel in transportation; however, in China, there has been no precedents of refueling with bio-diesel in gas stations, which restrained utterly the application scale of bio-diesel, and count againstits promotion and application. At the same time, aviation biofuel has its own bottleneck as well (He, 2011). Firstly, the current price of aviation biofuel is 1.5 – 2 times of that of traditional aviation gasoline. Secondly, there's also problem with resource supplyment of biofuel production, as the amount of plant cultivation is still limited, which also makes how to obtain the sustainable supplymental resource an issue as well.

Table 5-3 Applicaiton Situation of Bio-diesel in Land Transportation

<table>
<tr><th colspan="3">Application Situation of Bio-diesel in Land Transportation</th></tr>
<tr><th colspan="2">Country</th><th>Situation Description</th></tr>
<tr><td rowspan="3">America</td><td>The USA</td><td>• In 1980, national energy policy was issued demanding reducing sulfur content in diesel and waste gas discharge, boosting the business application of bio-diesel.
• Supporting the development of bio-diesel from the Congress;
• FDA and EPA admit bio-diesel as clean environmental protecting replacement energy or fuel additive;
• Preferential benefits are granted to the automobile using bio-fuel.</td></tr>
<tr><td>Brazil</td><td>• In 1980, the first country obtaining bio-diesel technology, with annual production once up to 500 million tons</td></tr>
<tr><td>Canada</td><td>• Mature Technology in bio-diesel</td></tr>
<tr><td colspan="2">Europe</td><td>• Europe is currently the main area using and promoting bio-diesel with over half of the total production of bio-diesel in Europe
• EU considers biofuel as main replacement energy, issuing Biofuel Strategy of EU, planning to increase the transportation biofuel utilization proportation up to 25% by 2030.
• Countries in EU reduced tax rate of bio-diesel.
• Since 2009, market share of bio-diesel in fuel market has been up to 12%.</td></tr>
<tr><td rowspan="2">Asia</td><td>Japan</td><td>• Japan is one of the countries developing bio-diesel the earliest, and also the biggest bio-diesel production country in Asia with annual production of 400 thousand tons.</td></tr>
<tr><td>India</td><td>• In the starting phase</td></tr>
</table>

	Thailand	• Cooperating with Japan in bio-diesel business
	S.Korea	• Starting bio-diesel business
	Philippine	• Starting bio-diesel business
	Indonesia	• Starting bio-diesel business
	China	• Starting research and exploitation in the early 1980s, currently in the phase of promotion gradually

Table 5-4 Bio-diesel Application Domain in Land Transportation

Bio-diesel Application Domain	
Country	**Application domain**
The USA	Mainly in environmental sensitive area and regions, including state government vehicle team, city buses, trucks, water transportation, parks and mine area
EU	Utilization Policy of Replacing Automobile Fuel of EU Transportation Department was issued in 2003, demanding the utilization proportion in automobile fuel consumption reaching 2% by 2005, 5.57% by 2010, and 8% by 2015
S. Korea	Bio-diesel has been produced and used in city cleaning vehicles and trash transmission vehicles
China	Years ago, used in agricultural dynamic machines and chemical products. In Feb. 2011, bio-diesel and fuel (B5) was allowed to enter the selling system of product oil as legal vehicle fuel.

Seen from the tables, the USA and EU are the areas where a series of preferential policies have been designated the most for the development of bio-diesel. Hence, currently the USA and EU are also the areas containing the most mature bio-diesel technology, which has been mainly utilized in vehicle industry. In Asia, many countries started to pay more attention on the research and exploitation of bio-diesel. Taking Japan as the forerunner, Asian bio-diesel industry is developing gradually. In China, the research on bio-diesel started late accordingly, however, has been evoked sufficient importance attached by the government and other relevant enterprises and researching units. However, the utilization of bio-diesel as legal vehicle used fuel in China is 30 years later than that of the USA, which requires still a long period to reach the prevailing level.

6. The biofuel benefit and deficiency in China

6.1. Benefit brings by biofuel

Researchers of University of Minnesota in US assert that both ethanol and biodiesel are considered clean energy, and environmental benefits of biodiesel is more obvious. Biodiesel has 41% lower greenhouse gas emissions compared with regular diesel and bio-ethanol has 12% lower greenhouse gas emissions compared with gasoline. A report from transport department of Finland stated that in 2011, the carbon dioxide emissions from the transport sector in Finland was 13.22 million tons totally which decreased 210k tons compare with the previous year, at the same time the traffic volume increased by 1%. The main reason is the use increment of biofuels, with increased by 6% in 2011.

In 2010, the total greenhouse gas discharge of the whole Chinese transportation system was up to 0.7 billion tons; According to the prediction of IEA, this number will increase to 2.3 billion by the year 2030 (Meng, 2012). Indicated in the report of the Ministry of Environmental Protection of the People's Republic of China, the total discharge pollutant of all motor vehicle is up was up to 52.268 million tons, which was the major resources of air pollution and also the most significant and urgent problem for atmosphere environment (Meng, 2012). Controlling transportation discharging pollutant is extremely urgent now. Ethanol as a vehicle used replacement fuel has been promoted in the USA, China and Brazil. Since 2004, China has demonstrated the usage of ethanol gasoline in six provinces as well as 27 cities, verifying the reduction of pollutant and greenhouse gas discharge. Thereinto, ethanol gasoline could reduce the discharge of carbon monoxide by over 35%, and hydrocarbon over 15% (Meng, 2012).

Although the carbon dioxide produced by aviation kerosene only 3% of all human emissions, the ability to produce the greenhouse effect and damage is much larger than the other. Compared with traditional aviation fuel, aviation biofuels in the life cycle reduces greenhouse gas emissions by 50% -90%. If use properly, aviation carbon emissions can be reduced by up to 80%. Nowadays the haze environment is more serious, aviation biofuels with carbon cleaning characteristics really fits the needs of sustainable development. What's more, there are a large amount of biomass material resources. Aviation biofuels is an important alternative to fossil fuels. In October 2011, biofuel was used as aviation fuel in successful aviation experimental flight, which indicated the potential of using biofuel as aviation fuel. Especially in 2012, EU accepted aviation into the Emissions Trading Scheme, which will boost the utilization of biofuel as well. In March 2015, biofuel made by Sinopec was used as aviation fuel in a Boeing 777 from Shanghai to Beijing, which means China is the fourth country has developed and successfully commercialized the biofuel technology after United States, France and Finland. Sinopec asserted that aviation biofuel is low-carbon and environmentally friendly, which could significantly reduce greenhouse gas. Thus, aviation biofuel will provide support for the target that reduce carbon dioxide emissions per unit of GDP by 40% -50% in 2020 in China. Next step Sinopec will accelerate the commercial production of biofuel. also Sinopec considers to build an aviation biofuel production base in Sichuan province.

In order to promote the discharge reduction of transportation system, The Twelfth Five-Year Plan for Traffic Transportation issued requirements towards highways, aviation, shipping departments for discharge reduction, demanding the proportion of road unit transportation volume and carbondioxide discharge decreasing by 11 – 12% comparing to 2005, with Shipping transportation 14 – 16% and civil aviation over 3% compared to 2010 (Kang et al. 2012). It is remarkably meaningful to protect and improve the atmosphere environment via the massive utilization of biofuel. Compared to fossil fuel, firstly, the CO2 discharge of using biofuel is much lower than that of regular fuel. Secondly, the utilization of biodiesel produces much less atmosphere pollutants such as NOx and SOx. Finally, the massive development of energy agricultural forestry could also efficiently afforest barren mountains and lands, decreasing soil erosion and water loss. According to the statistics of the Energy Institute of China, by the year 2050, the development amount of biodiesel is predicted to be up to 105 million tons, which means that 30 million hectares of barren mountains shall be afforested, with 310 million tons of CO_2 discharge reduced. China obtained significant environmental benefits by biofuel industry. Biological liquid fuel has been widely used as replacement fuel in transportation domain, to decrease pollutant and greenhouse gas discharge.

6.2. Deficiency compared with developed countries

Currently, the prevailing domains of biomass energy exploitation in China is focussing on selecting and cultivating energy plants of high efficiency, high production and stress resistance, which "does not compete for grains with people and does not compete for land with grains", and the key process optimization and technology exploitation which enables transformation from energy plants into applicable fuel. At present concerning the researches of biomass energy, the gaps between western developed countries and China are listed as follows.

The gap of production scale is huge. The scale of western biomass energy corporation is bigger, with biomass fuel centralized to some extent, large-scale pneumatolysis devices, the consciousness of environment protection and energy saving, the wholesome legislation, great fund investigation, and high automation level. However, currently in China, rural biomass energy processing enterprises are mostly medium or small models with decentralized operation. Although the biomass statistics absolute value is big, it is still hard to be convergently utilized, which limits the choices to small model units.

In terms of the research and experiments of fundamental theories and specialized technologies the gap between China and developed countries is still huge . Compared to the biomass gasification technology in developed countries, China is still to a large extent undeveloped in this area, especially concerning practical application, there is so far still issues concerning atmospheric pressure fixed bed, including low value in calorific value of gas and fuel utilization rate, and incomplete purification of gas.

Biomass energy product is lack of marketing competence. Under the current condition of energy prices, biomass energy products are lack of marketing competence with low return on investment (ROI), which frustrates the investing interests of investors. On the other hand, the high selling price decreases the enthusiasm of consumers as well. The technical standard has not been formalized when marketing administration is of chaos in the same way. Concerning the exploitation of straw gasification gas supply and methane engineering, there has been no proper technical standards and strict technical supervision, which results in the fact that many incompetent departments and individuals took over the contracts of methane engineering and the production and sales of straw gasification gas supply instruments, with limited technologies leading to unpredictable security issues.

In the following several years, the energy structure of Chinese transportation department will be changed dramatically (Figure 6-2), with an increase in the proportion of replicable energy and accordingly a decrease in the proportion of traditional energy resources. All of these Deficiencies are the development direction of China Biofuel industry in the future.

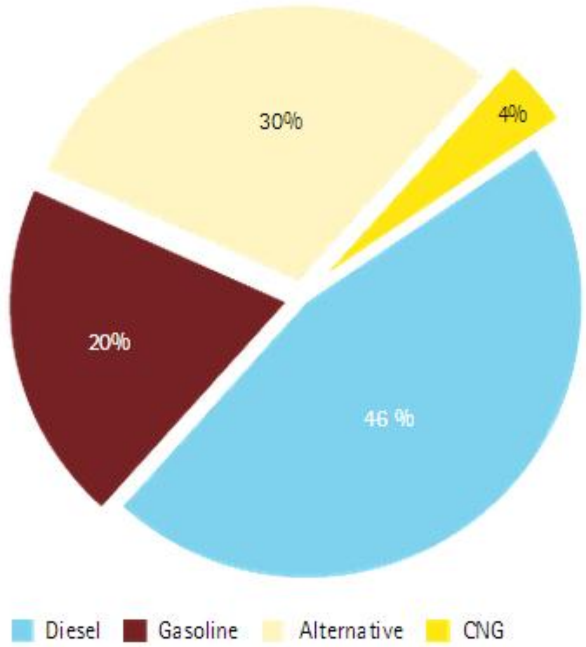


Figure 6-1 Energy structure projection in China’s transportation sector by 2020 (Accenture, 2011)

7. Conclusion

Accompanied with the increasing severity of resource failure and environment problems caused by the massive utilization of fossil fuels, the development and utilization of biofuel has been attached great importance by many national governments worldwide. This paper is aiming to describe in detail the effort towards wider scale biofuel production in China, in terms of biological resources collection, transmission and technology development, despite of the lack of policies, immature technologies and market, as well as the breaking progress of biofuel used in Chinese highway transportation and aviation industry.

The technology development of biomass fuel is a constantly popular research theme. As a key step of transforming materials (lignocellulose) into energy, pretreatment technology has become a focus for scientific researchers. Traditional chemical treatment and mechanical treatment technologies result in wasting energy and various levels of environmental pollution. With advantages of short time, low chemical medicine amount, no pollution and low energy cost, steam explosion has been one of the most promising pretreatment technologies. Concerning costs and instruments, biological pretreatment technology has unique advantage; however, the treatment efficiency is low. Transforming fungus and enzyme by using genetic engineering and traditional biotechnology could increase enzyme activity and decrease enzyme cost, which is also expected to be used in industrial production. To sum up, combining different pretreatment methods, and developing more pretreatment methods of higher efficiency, lower cost and no pollution will be the future development direction of biomass material pretreatment. In addition, within the process of storing, transmitting and feeding biomass materials, different material will be treated with different instruments and methods, which could reach the best production efficiency, profits and the lowest loss for biofuel.

Despite of the fact that the discharge reducing effects and economic efficiency evoked disputes, biofuel is still prone to the sustainable development of human race. First, the economic value of biofuel lies in the fact that it is a new option of energy sustainable development, bringing variety of energy, easing energy crisis. The laxation of energy crisis directly eased the pressure of international commissariat flow, which has been widely recognized as the crucial step of solving commissariat problems. Secondly, developing biofuel requires huge amount of manpower and resources, which stands for huge amount of job opportunities, spurring the development of newly born industry as well, changing the current producing pattern of agriculture, and reducing the industrial chain of agriculture and industry. In addition, the development of biofuel breaks the monopoly of new energy channels, providing protection on economic security.

Despite that there’s huge difference between the natural condition and technology level of different countries, and the future utilization of biomass energy, in sum, the future development of biofuel will not be as increasingly dispirited as the recent 200 years, but be of great importance instead, and will play an important role in the whole primary energy system. It is predictable that biofuel industry in China will have a bright future.

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