Development of the World Fuel Ethanol Industry

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Abstract This paper summarizes the developmental courses of fuel ethanol in the world. Then, it analyzes the existing problems and development prospects of fuel ethanol.
Key words Energy crisis, Environmental pressure; Renewable energy; Fuel ethanol

Energy is a long-term problem related to the future development of the world. It has become a growing urgency for all the countries due to environmental pollution and high price of oil. Fuel ethanol, a renewable clean fuel, is more and more appealing to many countries, and is incorporated into the strategic plan of the national security of the United States. However, development of fuel ethanol industry needs a great number of crops as raw materials, which might raise the global price significantly. What's more, large area of tropical rain forest is used as the arable land of economic crops, which might do more harm than good to the environmental protection. All the problems mentioned above have made fuel ethanol become the focus of attention. And in this paper, I objectively analyze the experiences and lessons learned from the development of world fuel ethanol.

1 Development review of the world fuel ethanol industry

1.1 Developmental status and planning of fuel ethanol in the United States

1.1.1 Background for the development of fuel ethanol industry. First of all, the energy issue has caused serious negative impact on the national economy. Fluctuation in the price of world crude oil has affected the life of normal family and the business operation. When the oil price fluctuates within a certain scope, the flexibility of U. S. economy can function effectively. However, its regulation will be ineffective if beyond the scope, which might be a death-blow to the economy.

Secondly, national security is facing crisis. On the one hand, the increase in oil price will enhance the impact of oil-exporting countries, such as Iran and Venezuela, on the United States, and will cause an increase in the costs of diplomacy, politics and military in the United States. Therefore, the United States must disengage from oil dependence on unreliable countries due to national security. On the other hand, terrorism attacks the United States mainly by destroying the global facilities of petroleum transport.

Thirdly, environmental problem becomes serious. Results of a survey by the International Energy Agency have shown that the carbon dioxide emission of United States, China, Russia and Japan accounts for almost half of the global emission. Among them, carbon dioxide emission in the United States ranks the first with annual per capita carbon dioxide emission of 20 t/a, occupying 23.7% of the global carbon dioxide emission.

1.1.2 Development course and future trend of fuel ethanol in the United States. In the year 1930, the United States sold ethanol fuel in California for the first time. During the world oil crisis in the year 1973, Brazil and the United States took the lead in implementing the "alcohol fuel program". The U. S. Congress established the "ethanol development plan" of federal government in 1979 in order to reduce its dependence on imported crude oil, and to search for an alternative energy. Under this background, the United States began to vigorously promote a kind of fuel blended with 10% ethanol. Implementation of the federal plan promoted the rapid development of ethanol industry in the United States. And ethanol production increased significantly from 0.45×10^8 L in the year 1979 to 39.55×10^8 L in 1990. Later, the U. S. Congress approved the Clean Air Act Amendment in the year 1990. As a result, ethanol as one of the main oxygen-containing compounds was widely used in the production of oxygenated gasoline and reformulated gasoline. California governor Davis announced on March 25, 1999 that based on the impact of MTBE on the environment of California and the health of residents, MTBE would be forbidden in California since January 1, 2003 under the framework of the Clean Air Act. The U. S. Congress passed the Renewable Fuel Standard in August, 2005. It is forecasted that consumption of bio-fuels will reach at least 340.96×10^8 L until the year 2012, which will bring 20×10^4 job vacancies, reduce oil imports by tens of billions of dollars, and increase family income by 430×10^8 U. S. dollars[1]. According to the statistics of the American Petroleum Institute, corn ethanol of the United States was more than 190.00×10^8 L in the year 2006, increasing by 35% compared with that in 2005. Meanwhile, gasoline with ethanol additives accounted for more than 40% of the gasoline on sale in the United States. The Department of Energy announced a new road map for the development of clean fuel on July 7, 2009; and they would make great efforts to substitute ethanol for gasoline by hydrolyzing from plant fibre. This road map was put forward according to the objective formulated by the Department of Energy, which is that by the year 2030, bio-fuels should substitute for traffic fuel with the quantity of 30% of the

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consumption in 2004.

The Presidential Union Message on January 23, 2007 by Bush pointed out that the United States would reduce the gasoline consumption by 20 percent in the next 10 years by developing alternative energy sources and improving energy efficiency. Among them, alternative fuels will be used to reduce 15 percent of gasoline. That is to say, ethanol production will reach 1 591.13 $\times 10^8$ L in the year 2017, which is about 15 percent of the gasoline consumption in the United States in 2017.

Although the fuel ethanol has been developed in the United States for more than half a century, its pace of development is still accelerating, and its impact on all levels of the world is increasingly far-reaching. We can learn from the remarkable results in promoting fuel ethanol. Firstly, the legislative acts of the government have played a substantial promoting role. Secondly, when implementing the fuel ethanol and other deep-processed products, enterprises can carry out the output structure adjustment and varieties regulation according to the market demand. Thus, enterprises can realize the balance production, the stable operation of production facilities, and more prominent economic benefits. Thirdly, production enterprises of fuel ethanol mainly locate in the main producing areas of raw materials. And the resources and markets of deep-processing products are extremely complementary. Fuel ethanol enterprises in the United States are built on the corn land, and can realize in situ processing of products. Fourthly, agricultural products have realized mechanization; and raw material of fuel ethanol costs lower. Meanwhile, rapid development of fuel ethanol again stimulates the development of agricultural production. Then, income of both fuel ethanol enterprise and peasants are increased. Thus the virtuous circle is achieved.

1.2 Developmental analysis of fuel ethanol in Brazil

1.2.1 Specific background for the development of fuel ethanol. Brazil has the most suitable geographical environment for the growth of sugarcane. And sugarcane is a well-known source of raw material rich in ethanol. Brazil is a country with the world's lowest cost of energy agriculture. The cost of a barrel of bio-diesel is only 26 U.S. dollars. Therefore, as long as oil price is more than 30 U.S. dollars a barrel, bio-energy production of Brazil is competitive.

Meanwhile, policy made by the military government of Brazil has promoted the rapid development of fuel industry to a large extent. The proven reserve of oil and natural gas in Brazil at present is second only to Venezuela in Latin America, and has realized self-sufficient. However, nearly 90% oil of Brazil was dependent upon import at the first oil crisis, and Brazil's national economy suffered a heavy blow. Based on the national energy security and economic development, Brazil carried out the national ethanol program in 1975. At that time, about 90% of the fuel supply counted on foreign oil. Government offered subsidies for sugarcane cultivation, and forced gas stations to install ethanol pumps in the cities and towns with more than 1500 population. Until the early 1980s, almost all vehicles on sale used ethanol fuel. Drivers could fill their car up with ethanol in anywhere of the country due to the distribution system established by military regime.

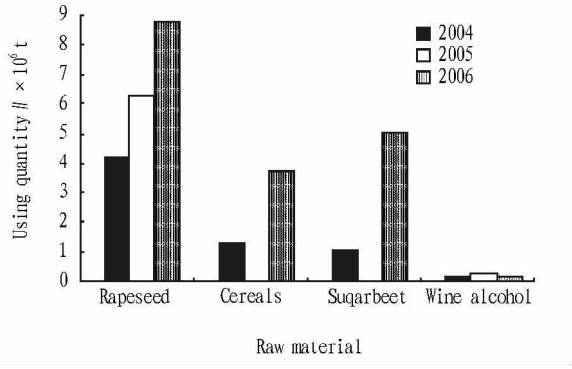
The last specific background is the breakthroughs in science and technology. ① Production efficiency of Brazil's ethanol had increased by eight times at the beginning of the 21st century. Production cost reduced from 60 cents per liter to about 20 cents, which had sufficient market competitiveness. ② Volkswagen (Brazil) introduced the first "flexible fuel" vehicle to Brazil market in the year 2003, which could use ethanol and gasoline fuel at the same time. The emergence of such a vehicle has played a very important role in the development of fuel ethanol.

1.2.2 Application status and future trends of fuel ethanol production in Brazil. Sugarcane production increased from more than 1.00 $\times 10^8$ t in the year 1976 to 3.50 $\times 10^8$ t in 2003, and the yield per unit area enhanced from 50 t/hm^2 to 70 t/hm^2. Fuel ethanol which was refined from sugarcane rose from 2 204 L/hm^2 to 5 500 L/hm^2. Brazil has more than 370 sugarcane processing plants. Their annual output of fuel ethanol is 160 $\times 10^8$ L; export volume is 19 $\times 10^8$ L in the year 2004, and 21 $\times 10^8$ L in the year 2005. In 2006, sugarcane ethanol export in Brazil is 30 $\times 10^8$ L, accounting for 70% of the world exports of sugarcane ethanol. Among them, 58.9% sugarcane ethanol is exported to the United States, and 11.5% to the Netherlands; and the rest are sold in Japan, Sweden and other countries. Brazil harvests 5.28 $\times 10^8$ t sugarcane in 2007, and 2.37 $\times 10^8$ t of them is used for ethanol production, which can produce 200 $\times 10^8$ L ethanol. Ethanol production in 2007 increases by 14.54% over the same period, and hits a record high. The minister of agriculture has announced that Brazil plans to enlarge the annual output of ethanol fuel to 350 $\times 10^8$ L, among which 100 $\times 10^8$ L ethanol fuel will be used for export[2].

After many years' efforts, Brazil has become the largest producer of ethanol; at the same time, its production technology grows mature. Brazil is one of the most successful counties in the field of substituting ethanol fuel for oil. And it is the only country does not supply pure gasoline. Except for the unique natural conditions, the successful development of fuel ethanol industry in Brazil is mainly reflected in the following aspects. Firstly, just like the United States, legislation has played a substantial promoting role. Secondly, operation of the government support policy is perfect; and subsidies and tax relief plans have strong attraction to enterprises. Thirdly, actively carry out international cooperation, attract foreign capital to invest in the dominant industries, and actively seek for the international market.

1.3 Development and regulation introduction of fuel ethanol industry in Europe and other areas The European Commission passed a resolution in March 2007 so as to set objectives for the EU members. It requires that the bio-fuels in EU members should account for 10% of the transport energy consumption by the year 2020. The European Bioethanol Fuel Association (EBIO) has released the latest information that the bio-ethanol fuel production in Europe in the year 2006 is 15.65 $\times 10^8$ L, increasing by 71% over the same period [3]. Bioethanol production in Europe is 9.13 $\times 10^8$ L in 2005, while

the annual output is only 5.28×10^8 L in the year 2004[3]. Among them, bio-ethanol production in Germany reaches 4.31×10^8 L, which has increased greatly compared with 1.65×10^8 L in 2005. The second largest producer is Spain, its bioethanol output is 4.02×10^8 L in 2006 (3.30×10^8 L in 2005). France takes the third place. And its bioethanol output is 2.50×10^8 L in 2006. Italy shows the fastest increase in production, and its output is 1.28×10^8 L in 2006 (only 0.08×10^8 L in 2005). The bioethanol output of Poland is 1.20×10^8 L in 2006 (0.64×10^8 L in 2005). Bioethanol fuel consumption of the EU reaches 170×10^8 L in the year 2006. Import from Brazil to Sweden, Finland and the United Kingdom is about 2.3×10^8 L. Unlike Brazil and the United States, the EU mainly uses rapeseed to produce fuel ethanol (Fig. 1).



Note: Data are from the 2007 Agricultural Outlook Forum of USDA.

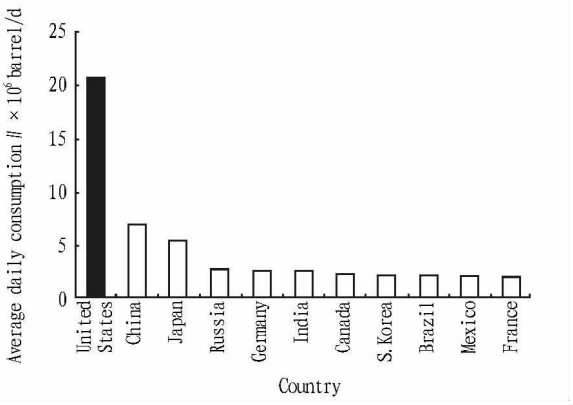
Fig.1 Proportion of the raw materials of fuel ethanol from 2004 to 2006

Canada implements the duty-free ethanol policy, and supports the development of bio-fuels, which is an important measure to reduce greenhouse gas emissions. According to the federal budget in 2007, Canadian Federal Government ought to allocate 2 billion Canadian dollars to support the production of renewable fuels in the next 7 years. In addition, government has announced to input 0.5 billion Canadian dollars. "Bio-fuels and Bio-product Plans" can assist farmers and rural communities in developing new market opportunities for bio-economy. According to the news from Canadian government network, the minister of Federal Ministry of Agriculture and Food has announced that the eco-agriculture biofuel capital plan is officially launched. This plan aims to help farmers to construct and expand the production facilities of biofuels in order to increase the production of renewable fuels. To reduce emissions and greenhouse gas, Canadian government has promised that the average content of renewable fuels in gasoline will reach 5% in the year 2010, and that in diesel and heating oil will be 2% in the year 2012.

Ministry of the Environment in Japan decided that the vehicle use gasoline sold in Japan would be changed into mixed fuel (E10) with 10% bio-ethanol and 90% gasoline until 2030. According to the plan of the Ministry of the Environment, replacement of motor gasoline should be a process step by step. 50% of the fuel in Japan will be replaced by fuel E3 (3% ethanol). Japan will begin to supply fuel E10 from the year 2020. And by 2030, all cars in Japan will be filled with fuel E10. The Japanese government will invest 8 billion U.S. dollars to buy part of the stock rights of 40 ethanol distillation plants in Brazil, which can offer stable energy supply for the mixed fuel program of gasoline and ethanol in Japan.

2 Development process of fuel ethanol industry in China

2.1 Implementation background of fuel ethanol industry in China Development of fuel ethanol in China can be traced back to the Anti-Japanese War. As a result of the Japanese blockade and the needs of the war, fuel ethanol industry has developed rapidly in the rear. There were more than 50 fuel ethanol companies in Henan, Shaanxi and Sichuan provinces at that time with annual output of more than 3×10^4 t. After a certain period of time, related research on fuel ethanol was carried out, but the research result could not put into practice due to various reasons. Until the 1990s, fuel ethanol was again promoted in order to digest the huge corn stocks. When China becomes the second oil-consuming countries of the world (Fig. 2), the pressure of energy is imminent. Therefore, development of fuel ethanol becomes an environmental-friendly and energy-saving choice. Until recently, China has already become the world's third ethanol fuel producers and users. China's fuel ethanol output is 68×10^4 t in 2004, 81×10^4 t in 2005, and more than 100×10^4 t in 2006. Fuel ethanol is widely promoted and used in the fuel market of motor vehicle in 9 provinces of China.



Note: Data are from the Energy Information Administration in the year 2005.

Fig.2 Major oil consuming countries in the world

2.2 Development of fuel ethanol industry in China in recent years China's fuel ethanol has carried out pilot work since 2000. National Development and Reform Commission together with 7 ministries compiled the promotion planning for fuel ethanol. National standards for two products (the Denatured Fuel Ethanol and the Vehicle Use Ethanol Gasoline) are officially introduced on April 2, 2001. The former State Development Planning Commission and the General Administration of Quality Supervision, Inspection and Quarantine have announced on April 8, 2001 that China will promote the use of fuel

ethanol. Some areas of Henan, Heilongjiang, Jilin and Anhui provinces carried out the trial on fuel ethanol on June 30, 2002, and achieved great success. However, development of fuel ethanol is slow due to the high price. National output of fuel ethanol is only 3×10^4 t in 2002. And the price of fuel ethanol in 2004 doubled as a result of the rise of global energy and oil prices. Under the support of a series of fiscal and taxation policies, fuel ethanol has turned to capture the market. And the production enterprises eventually have gained certain profit. The 4 pilot projects of bio-fuel ethanol production approved by the state in 2006 have achieved the production ability of 102×10^4 t/a in all. Among them, production of Heilongjiang Huarun Alcohol Co., Ltd. is 10×10^4 t/a, and those of Jilin Fuel Ethanol Co., Ltd., Henan Tianguan Fuel Ethanol Co., Ltd., and Anhui BBCA Biochemical Co., Ltd. are 30×10^4, 30×10^4 and 32×10^4 t/a, respectively. The Ministry of Finance has implemented the *Interim Measures on Special Fund Management for Development of Renewable Energy* at late May, 2006. Bio-ethanol fuel is defined as a fuel made from sugarcane, cassava and sweet sorghum, which does not include the fuel ethanol made from corn, wheat, rice and their aged grains. This indicates that the government no longer encourages, and even restricts, the fuel ethanol project using new grains as raw material. The Development and Reform Commission and the Ministry of Finance have distributed the *Circular on Strengthening Construction Management of Bio-fuel Ethanol and Promoting Healthy Development of Industries and* the *Urgent Circular on Strengthening Management of Corn Processing Projects* on December 18, 2006. The two circulars try to bring down the fuel ethanol project. And at the same time, they are the new turning point for the production of ethanol fuel by using "non-grain" as raw materials.

2.3 Existing problems and future development trend of China's fuel ethanol

2.3.1 The main technical problem for the development of China's fuel ethanol is the high cost. Table 1 reports the comparison among the production costs of fuel ethanol in relatively developed countries.

Table 1 Comparison among the production costs of fuel ethanol in different countries

Country	Main raw material	Production cost U.S. dollar/L	Output in 2006 10^8 L
The United States	Corn	0.33	190.00
Brazil	Sugarcane	0.20	175.00
Europe	Wheat	0.48	15.66

Note: Data come from the Information Network of Rural Energy Industry in China.

The *Status and Prospects of Fuel Ethanol Industry in China-Industry Research White Paper* offered by the world's leading advisory body ATKearney shows that the production cost of fuel ethanol industry in China is 17 percent higher than that in the United States at present; while price of ethanol in China is 18 percent lower than that in the United States. Therefore, China's ethanol production must rely on government subsidies to break even or obtain profit. Fuel ethanol production in China and the United States have great differences in efficiency. Every 1 t ethanol needs to consume 12 t water in China, which is only 1.8 t in the United States. China needs 3.3 t corn to produce 1 t ethanol, but the United States only needs 2.8 t corn. What's more, emission from ethanol production in China is much more serious than that in the United States. In consideration of food security, China can not cultivate crops for ethanol production in large area like Brazil does. Therefore, higher resource utilization becomes an inevitable requirement for China.

2.3.2 Future development trend of fuel ethanol in China. The first development trend is to realize the non-grain transformation of raw materials. At present, fuel ethanol production in China is mainly distributed in the four appointed companies mentioned above. Except for Henan Tianguan Fuel Ethanol Co., Ltd., the rest three companies use corn as the main raw material. Moreover, these four appointed companies are making efforts to improve the productivity proportion of non-grain raw materials. Cellulosic ethanol has huge resources potential in China. According to the statistics of the Ministry of Agriculture and Forestry, the available agro-forestry and crop waste and other resources are 6×10^8 t in all, which has the potential to produce 3×10^8 t fuel ethanol. Henan Tianguan Group began to construct the cellulosic ethanol project with 3 000 t annual output. And this is the first industrialization line for fiber ethanol in China. Ethanol production made from cellulosic material of straw will become a reality when this production line is established, which has far-reaching significance. COFCO Power and Energy Department has also made specific plans. They are setting up a pilot plant with 5 000 t of annual fuel ethanol and total investment budget of $4\ 500 \times 10^4$ yuan using corn straw as the raw material. COFCO has already established partnerships with Novozymes Company in Danmark, which has the world's leading technology. They will realize a large-scale production of cellulosic ethanol within 2 or 3 years. The second development trend is to pay attention to the use of intermediate products and final products[4]. First of all, production of fuel ethanol has the same production process with high-quality and high-protein feedstuff. It is the value-added optimization process of feed protein resources. Taking ethanol production by traditional raw materials as an example, every 1 t production of ethanol needs about 3 t corn, and can produces 1 t DDGS protein feed. Secondly, with the maturity of technology and the increasing supply of fuel ethanol, application field of fuel ethanol will transit from the current traditional automobile to the flexible-fuel vehicles, the pure ethanol-fuel vehicles, the diesel vehicles, and the fuel cell.

3 Existing problems and prospects of the development of fuel ethanol industry

3.1 Disputes in the development of fuel ethanol

3.1.1 Negative impact on the development of fuel ethanol industry. As is known to all, the original intention for each country to develop fuel ethanol industry is to reduce the carbon dioxide emissions, and to clean up the air. However, the sharp increasing requirements of palm oil have led to the destruction of tropical rain forests in Southeast Asia. Consequences of such

destruction may be more serious than the greenhouse gas emissions of fossil fuels. Taking Brazil as an example, the pollution will be more serious if the cultivation of sugarcane threatens the Amazon rain forest, and carbon dioxide emissions reduced by the utilization of ethanol is less than the absorbing capacity of original rain forest. Meanwhile, sugarcane is a crop needs a large quantity of water. In areas with insufficient rainfall, peasants must use surface water or groundwater. Therefore, planting sugarcane will cause even greater pressure on the increasingly intense supply of fresh water. In addition, sugarcane in Brazil is invading the land for grain, orange and pasture. Thus, sugarcane will seriously affect the balance of ecosystem.

3.1.2 Causing the price rising of the world. At present, raw materials of fuel ethanol industry in the United States are basically the corn. But the price of corn has bid up to a new high over the last two years[5]. The United States is the world's major exporter of corn. Cumulative export sale of corn from 2008 to 2009 is 2 371.11 $\times 10^4$ t in the United States, which is far lower than the 4 631.97 $\times 10^4$ t over the same period from 2007 to 2008. Meanwhile, a lot of land is used to plant certain crops in order to produce biofuels, which leads to the price rising of other basic living supplies. Although countries may adjust the policy objective in the short term in order to influence price or make it stable, world grain price will continue to rise unless there is a breakthrough in technology according to the planning of fuel ethanol industry in the world[6]. Increase in the price of primary product in resource category is bound to affect the general price level.

According to the estimation of Lester Brown in Worldwatch Institute, the corn needed for a tank of SUV car to fill with bioethanol is just the food ration needed for a person per year. Lester Brown describes the ethanol boom as a kind of competition between the 800 million people owning cars and the 3 billion people who live on less than 2 U.S. dollars a day.

3.2 Road and prospect for the development of fuel ethanol industry Through the above-mentioned summary of the fuel ethanol development, it is not difficult to find out that the original intensions for different countries to develop fuel ethanol are exactly the same, which are easing the energy and environmental crisis and increasing the employment opportunities, though they have different natural endowments and technical advantages. At the same time, the world has been aware that cellulosic ethanol is just the material to replace fuel ethanol. Cellulosic materials include grass, sweet potato and other crops, as well as straw, branches, leaves and crop hull. Although it is feasible to use the non-grain raw materials to produce cellulosic ethanol, there has been no successful business operation yet in the world due to the high costs. There will be a competition for technological superiority of cellulosic ethanol among countries in the next few years. Future is in the hands of the country which has made technical breakthroughs. In other words, country with technical breakthroughs will bring evangel to the world's energy and environmental crisis.

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世界燃料乙醇产业发展浅析

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摘要 分析了美国、巴西燃料乙醇产业的发展背景、发展历程及未来趋势,提出了其对中国燃料乙醇产业发展的启示:一是政府立法行为起到了实质性的推动作用;二是实行联产方式,可实现生产装置的稳定运行;三是燃料乙醇生产企业多坐落于原料主产区;四是农业生产实现了机械化,成本较低;五是政府的扶持政策运作良好;六是积极寻求国际合作、拓展国际市场。简述了欧洲及其他地区燃料乙醇产业的发展状况及相关政策法规。回顾了中国燃料乙醇产业的发展历程,包括中国燃料乙醇项目的实施背景、产业的发展动态,提出了发展中存在的主要技术问题,并展望了中国燃料乙醇的未来发展趋势:一是实现原材料的"非粮"转化,加大力度提高"非粮"原料的产能比例;二是重视中间产品利用与最终产品应用领域的扩展。介绍了发展燃料乙醇产业引发的一些争议:以巴西为例,分析了燃料乙醇产业发展的负面影响,即加重污染、破坏了生态系统的平衡:许多土地被用于种植某些农作物以生产生物燃料,致使其他基本生活物资价格上涨,从而引发了世界物价上涨。探讨了发展燃料乙醇产业的出路与前景:纤维素乙醇是燃料乙醇的发展方向,各国会在此项生产技术上展开科研竞争,以实现技术上的突破。

关键词 能源危机;环境压力;可再生能源;燃料乙醇