A Study of Directions for the Development of Ethanol Industry in Thailand

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SUMMARY

1. Introduction

As the domestic consumption of imported gasoline has a tremendous impact on the country's economic security, on December 26, 2000, the Thai government unanimously declared the national policy on promoting the production and used of bioethanol for blending with petroleum fuel. Bioethanol is renewable liquid energy obtained by bioprocess of agricultural raw materials. Therefore, the promotion of bioethanol production not only strengthens the nation economics, but also stabilizes the market price of agricultural materials. The objectives of this study was to report the global situation of ethanol production, the structure of ethanol industry in Thailand and the directions and effective plans of ethanol production and utilization.

2. Ethanol industry

2.1 World ethanol production

Table 1 summarizes the total volume of the world ethanol production since 1997-2001. The maximum production of ethanol was in 1997 for 32,993.9 million liters and decreased afterwards to the lowest in 2000 for 29,950.8 million liters. In 2001, the ethanol production increased to 31,394.9 million liters. The ethanol production is mainly in Americas for the total volume of 20,549.2 million liters, accounting for 65.5% of the world ethanol production. The second is in Asia which produces 5,959.5 million liters ethanol (19% of the world production). The third is in Europe producing 4,174.4 million liters ethanol or 13.2% of the world production. The last two producers are in Africa and Oceania which produces 532.4 (1.7%) and 179.4 (0.6%) million liters of ethanol, respectively.

Table 1 The world ethanol production in 1997-2001 (unit: million liters)

Continent \ Year	1997	1998	1999	2000	2001
Europe	4,350.4	4,147.5	4,092.7	4,043.9	4,174.4
Americas	22,296.9	21,490.4	20,560.6	19,506.8	20,549.2
Asia	5,656.3	5,672.1	5,779.3	5,731.3	5,959.5
Oceania	110.8	117.0	125.6	147.5	179.4
Africa	579.5	543.1	533.3	521.3	532.4
Total	32,993.9	31,970.1	31,091.5	29,950.8	31,394.9

2.2 Ethanol consumption

The world ethanol consumption as surveyed by Licht (2001) can be classified into 3 main groups as below.

2.2.1 Fuel ethanol

By far, fuel ethanol is the largest market, accounting for 66% of total ethanol. As an automotive fuel, two types of ethanol can be used. The first one is hydrous ethanol (95% by volume) which can entirely replace gasoline in the modified engine. This is only available in Brazil. The second one is anhydrous ethanol containing 99.5% ethanol (by volume). This anhydrous ethanol is used as an effective octane booster by mixing with gasoline in the amount of 5 to 30% ethanol in the unmodified engine. This product is commonly used in ethanol-producing countries such as “Proalcohol” in Brazil, “Gasohol” in USA and “Petratol” in Australia.

2.2.2 Industrial ethanol

The most important purposes of ethanol used in industry are as an organic solvent, which is able to dissolve, suspend or extract other materials without causing properties of material or solvent changes, and as the initial raw material of producing other chemicals. Chemical industry is the biggest consumer, accounting for 35% of total industry consumption, following with cosmetics (26%), detergents (10%), inks & adhesives (9%) and process solvents (6%), respectively.

2.2.3 Beverage ethanol

The use of ethanol for this purpose is smallest and has the lowest growth rate among these three applications. The difficulty in this market is that many distilled spirits are produced directly from agricultural materials such as grapes and malt without diluting food-grade ethanol having a very high concentration of 80-96%. In developed countries, the demand of beverage ethanol is declining due to increasing health awareness. In contrast, the demand of beverage ethanol in developing countries is still increasing as a result of western culture acceptance. The market of beverage ethanol in 2001 is 17,010 million liters, which is 7,560 million liters in China (45% of total beverage ethanol). Others are in Russia, USA, Brazil, Japan and South Korea.

The world consumption of ethanol as fuel is expected to increase in the future, as a result of national policy of many countries in replacing petroleum fuel such as USA, Brazil and others in Europe and Asia. In contrast, the consumption of ethanol as beverage is more or less unchanged as a demand decrease in developed countries balances with a demand increase in developing countries. The market of industrial ethanol is mainly depending on gross domestic product (GDP) of each country.

3. Process of ethanol production and raw material situation

3.1 Process of ethanol production

The process of making ethanol can be classified into 2 categories as following:

3.1.1 Synthesis process

Ethanol can be produced synthetically from petroleum derivatives such as ethylene (C_2H_4) by direct or indirect reaction. It can be obtained directly from ethylene by dehydration. Alternatively, ethylene can react with sulfuric acid to produce ethyl sulphate, following step hydrolysis to yield ethanol.

3.1.2 Fermentation process

Ethanol can be produced by sugar fermentation with yeast. Yeast uses monosaccharides as food source and then converts sugar, under the anaerobic condition, to ethanol via glycolysis pathway:

$$C_6H_{12}O_6 + \text{Yeast} \longrightarrow 2CO_2 + 2C_2H_5OH + 28.7\ \text{kcal}$$

3.2 Types of raw materials and current technology

3.2.1 Types of raw materials

There are many agricultural materials consisting of monosaccharides that can be used for ethanol production. The carbohydrate-containing materials can be categorized to 3 groups:

3.2.1.1 Sugar containing materials: Examples of this class are sugar cane, sugar beet and molasses. Yeast can directly utilize the sugars in materials without pretreatment.

3.2.1.2 Starch containing materials: Agricultural materials of this group are cereal, cassava and potato. For ethanol production, starch has to be hydrolyzed to glucose first so that yeast can further ferment glucose to ethanol. A complete hydrolysis of starch can be achieved by 2 stages including liquefaction and saccharification. Recently, an innovation of combining saccharification of liquefied starch and fermentation at the same stage has been introduced; this is called Simultaneous Saccharification and Fermentation (SSF) process.

3.2.1.3 Lignocellulose containing materials: These materials are mostly agricultural waste and by–products such as rice straw, bagasses, corn cobs and waste from pulp and paper industry. Typically, lignocellulosic materials constituents cellulose, hemicellulose and lignin. The process of ethanol production consists of three steps:

(1) Pretreatment: The purpose of pretreatment is to open and weaken the structure of cellulose bound with other components. The rupture structure can facilitate the hydrolysis and increase the susceptibility of cellulose to cellulase enzymes.

(2) Hydrolysis: The hydrolysis of cellulose can be accomplished by acid or enzymes. By acid process, initially the acid hydrolyzes hemicellulose (to pentose sugar) and the remaining cellulose can be further hydrolyzed.

(3) Fermentation: The glucose obtained from hydrolysis can be fermented to ethanol by yeast.

3.2.2 Current technology of ethanol process

The technology of ethanol production from sugar- and starch-containing materials are widely developed and utilized around the world such as BIOSTIL, HIFERM-GR and HOECHST-HDE. The production of ethanol from lignocellulosic materials is also practical with initial pretreatment of materials to facilitate hydrolysis of cellulose and hemicellulose of which the hydrolyzed products can be further continued to fermentation by yeast.

3.3 Current situation of raw materials in Thailand

Thailand has a very high capability for producing ethanol due to a high availability, production area and yield, of agricultural resources such as sugar cane, cassava, corn and rice. When considering the total planting area, rice has the highest (60 million Rais), the second is corn (8 million Rais), following cassava and sugar cane (7 million Rais). However, when considering the annual production yield, sugar cane has the highest (63 million tons), following rice (26 million tons) and cassava (18 million tons). Corn has the lowest productivity (4.5 million tons). Further, some primary products and by-products of these agricultural materials such as molasses, cassava chips, and broken rice are also considered for ethanol production by considering the production cost (Table 2). The production cost for ethanol production is highest when rice is used (16.20 Baht), following with corn, sugar cane, cassava roots and cassava chips (production cost of 11.23, 9.87, 6.76 and 6.25 Baht, respectively). The lowest production cost is 6.00 Baht when molasses is used. Based on the crop productivity, production cost and technological aspect, cassava and molasses are most suitable materials for ethanol industry.

Table 2 Production cost for ethanol production from various agricultural materials and by-products.

Agricultural materials	Amount of agricultural materials for 1L ethanol (kg)	Average price of agricultural material (Baht / kg)	Raw material cost for 1L ethanol (Baht)
Molasses	4.00	1.50	6.00
Sugar cane	14.30	0.69	9.87
Cassava starch	6.50	1.04	6.76
Cassava chip	2.50	2.50	6.25
Broken rice	2.70	6.00	16.20
Corn	2.70	4.16	11.23

4. Current situation of ethanol production in Thailand

Based on the information from the Department of Industrial Works, Ministry of Industry, Board of Investment of Thailand and the Excise Department, there are 4 factories producing 95 degree ethanol. Only one factory can sell this ethanol (95% by volume) domestically, the other two for export markets, and the last one for acetic acid factory.

(1) The Thai Liquor Distillery Organization. The Excise Department, Ministry of Finance, Chachengsao province. This factory is a state enterprise making distilled spirits, blended spirit, and ethanol with a production capacity of 55,000-60,000 liters per day or 18 million liters per year. This organization is a sole provider of ethanol in the country according to the cabinet approval of Liquor Management Policy on September 15, 1998.

(2) Eastern Chemical Co. Ltd., Cholburi province. The ethanol production is 25 million liters per year and for export market only.

(3) Thai Alcohol Co., Ltd., Nakorn Pathom province. The ethanol production is 132.32 million liters per year.

(4) Porn Vilai International Group Trading Co. Ltd., Ayudhaya province. This factory gets the license to produce ethanol for acetic acid production which the total ethanol consumption of 2.4 million liters per year. Currently, the company also receives the license to produce ethyl acetate of 5,500 tons per year and ethanol of 8,250,000 liters per year.

For the production of anhydrous ethanol (99.5% by volume), there are only two manufacturers which are the Pharmacy Organization, Ministry of Health and BecThai Co. Ltd. They buy the 95% ethanol from the Thai Liquor Distillery Organization for further distillation to produce anhydrous ethanol (99.5%).

There are two major types of ethanol production in Thailand:

(1) Ethanol: According to the act of liquor distillery, ethanol is distilled spirit having the ethanol content higher than 80%. Mostly, the produced ethanol is 95% by volume.

(2) Denatured ethanol: Denatured ethanol is a mixture of ethanol with other ingredients to make ethanol unfit to human consumption, but suitable for other applications according to the ministerial regulations of the Excise Department.

4.1 Current situation of ethanol production and consumption in Thailand

Since the Thai Liquor Distillery Organization is a sole provider of ethanol in the country according to the cabinet approval of Liquor Management Policy on September 15, 1998, all purchasers have to file for purchasing permission and the estimated annum volume of ethanol uses to the Excise Department or Provincial Excise office. The Excise Department further informs the total demand of ethanol to the Thai Liquor Distillery Organization to set up the production plan. The Thai Liquor Distillery Organization will know overall market demand and then produces with no ethanol stock over the year. Total volume of ethanol produced and sold domestically is summarized in Table 3.

Table 3 Volume of ethanol and denatured ethanol produced and sold domestically

(unit : liter)

Year	95% Ethanol	Denatured ethanol	Total
1996	76,629,043.00	5,498,940.00	82,127,983.00
	(93.30)	(6.70)	(100.00)
1997	89,347,857.00	4,445,560.00	93,793,417.00
	(95.26)	(4.74)	(100.00)
1998	65,868,467.00	3,506,360.00	69,374,827.00
	(94.95)	(5.05)	(100.00)
1999	79,004,980.00	4,341,776.00	83,346,756.00
	(94.79)	(5.21)	(100.00)
2000	92,512,451.00	5,178,600.00	97,691,051.00
	(94.70)	(5.30)	(100.00)
2001	129,706,490.00	4,584,076.00	134,290,566.00
	(96.59)	(3.41)	(100.00)

Note: the number in parenthesis is the percentage of production and consumption of ethanol and denatured ethanol

The production of 95% ethanol was continuously increased every year, which corresponds to an increase in gross domestic product (GDP) of the country. Ethanol can be used in many industries including food, chemicals and drug. The ethanol is sold to tax-privilege customers first such as hospital, educational institute, pharmaceutical and medical & science institutes, which accounting for 53.5% of total sold amount (data in 2001). Next, it is sold to industries producing perfume and medicine, according to the ministerial regulations No. 5, which has about 46% of total sold amount. The rest of 0.5% is sold to small purchasers.

4.2 Import and export of ethanol

The import of ethanol and denatured ethanol has continuously increased growth rate because of the market price of ethanol decreased. In 1991, Thailand imported ethanol totally

45,048 liters or 4,108,017 Baht with the price of 91 Baht per liters. In 2001, Thailand imported ethanol totally 1,086,782 liters or 54,851,570 Baht with the price of 50 Baht per liters. For denatured ethanol, Thailand imported a total amount of 541 liters or 21,004 Baht with the price of 39 Baht per liter in 1991. In 2001, Thailand imported denatured ethanol for 2,604,779 liters or 63,045,591 liters or 24 Baht/liter.

Based on the information on production capacity of the Thai Liquor Distillery Organization, the volume export and import of Thai Alcohol Co., Ltd. and Eastern Chemical Co. Ltd., the balance account of total ethanol (95% ethanol and denatured ethanol) can be obtained (Table 4 and Table 5).

Table 4 Balance account of 95% ethanol in 1996-2001

Unit : Liter

Year	Supply			Demand		
	Produced	Imported	Total	Domestic	Export	Total
1996	76,629,043	294,765	76,923,808	17,201,558	59,722,250	76,923,808
1997	89,347,857	740,571	90,088,428	20,023,608	70,064,820	90,088,428
1998	65,868,467	652,435	66,520,902	15,005,141	51,515,761	66,520,902
1999	79,004,980	853,588	79,858,568	31,769,815	48,088,753	79,858,568
2000	92,512,451	1,186,513	93,698,964	1,603,798	92,095,166	93,698,964
2001	129,706,490	1,086,782	130,793,272	16,684,904	114,108,368	130,793,272

Table 5 Balance account of denatured ethanol in 1996-2001

Unit : Liter

Year	Supply			Demand		
	Produced	Imported	Total	Domestic	Export	Total
1996	5,498,940	945,333	6,444,273	6,381,180	63,093	6,444,273
1997	4,445,560	945,171	5,390,731	5,389,620	1,111	5,390,731
1998	3,506,360	509,260	4,015,620	4,014,770	850	4,015,620
1999	5,341,776	795,498	5,137,274	5,118,038	19,236	5,137,274
2000	5,178,600	1,691,572	6,870,172	6,535,680	334,492	6,870,172
2001	4,584,076	2,604,779	7,188,885	6,912,715	276,140	7,188,885

From Table 4, it suggests that 95% ethanol has an increasing trend of production, import and export and domestic consumption. In 2001, Thailand imported ethanol 1,086,782 liters which increased around 3.6 times from 1996 (294,765 liters). This is very interesting that why ethanol has been imported in a higher volume even a higher price than the one sold domestically and the Thai Liquor Distillery Organization still has the production capacity of 7-8 million liters/year left. Based on the interview with users, it was found that the main reason was the inconvenience in filing for purchasing permission. The export market seems to have a promising trend, but relies mainly on Japan. The export as the joint venture with Japanese will provide technology transfer and market. Yet the government should consider if the Japanese pulls out.

4.3 Estimation of ethanol demand and supply

4.3.1 Estimation of ethanol demand

A total domestic demand of ethanol in Thailand originates from various industries including automobile (as fuel), beverage, painting & coating, cosmetics and export market. The analysis of ethanol demand has to estimate all practices including fuel use, domestic consumption and total import and export volume.

The estimation of ethanol demand for fuel use purpose is based on the national strategy, which is the environmental strategy in the first phase (10 years). The anhydrous ethanol is used as

the substitute of Methyl Tertiary Butyl Ether (MTBE) at 10% to produce gasohol. The estimation of 95% and denatured ethanol are suggested to be a growth rate of 7.40 and 1.49%, respectively. The demand for export market of 95% ethanol is also expected to increase at a growth rate of 14.0% while that of denatured ethanol is decreased at the rate of 0.84%. The import market for both 95% and denatured ethanol is estimated to increase by 8.56 and 16.09%, respectively.

4.3.2 Estimation of ethanol supply

The balance of ethanol demand and supply can be achieved by good production planning which is

Ethanol production = Demand for fuel use + Demand for domestic use + Demand of export market – Import volume (equation 1)

Different types of ethanol are available for uses, i.e. anhydrous ethanol (99.5%) for fuel purpose and hydrous ethanol (95%) for domestic using and denatured ethanol demand. For denatured ethanol uses hydrous ethanol (95%) with amount less than 1% of denaturing substances. Based on the 95% ethanol demand can be estimated a production plan for ethanol (Table 6).

The production of ethanol is expected to increase at a growth rate of 7.28% which a total production need of 677.46 million liters in 2004 increases to 1,275.54 million liters in 2013. Regarding ethanol supply, the production of ethanol produced by The Thai Liquor Distillery Organization and the private sectors is approximately 134.29 million liters for domestic uses, 114.38 million liters for export market in 2001 and the total volume of imported ethanol is 3.69 million liters (Table 4 and Table 5). Therefore, the total production of ethanol is around 244.98 million liters (equation 1). However, there are still some suggestions for ethanol supply and demand estimation.

Table 6 Demand of ethanol in various purposes and the estimation of ethanol production in 2004–2013.

Unit : Million liters

Year	Fuel use	Domestic use	Export	Import	Production need
2004	485.70	27.90	169.33	5.47	677.46
2005	513.50	29.54	192.99	6.24	729.79
2006	539.60	31.29	219.97	7.13	783.73
2007	564.50	33.17	250.72	8.16	840.23
2008	588.40	35.17	285.79	9.34	900.02
2009	611.60	37.33	325.76	10.70	963.99
2010	634.20	39.62	371.32	12.25	1,032.89
2011	656.50	42.09	423.27	14.06	1,107.80
2012	676.20	44.73	482.50	16.14	1,187.29
2013	696.50	47.56	550.01	18.53	1,275.54
Growth rate (%)	4.09	6.11	13.99	14.52	7.28

(1) An increase of ethanol demand, in fact, originates from the need of replacing MTBE in automobile fuel and has to be complied by the factories receiving the National Ethanol Committee's permit.

(2) The effective production of ethanol significantly relies on the raw material production in the country. According to the National Production Policy of Ministry of Agriculture and Cooperatives (2003-2011), a total planting area is defined with a total annual production of 20 million tons cassava roots. After a domestic consumption in cassava chips, cassava pellets and cassava starch industry, there is around 4 million tons of cassava roots surplus available for ethanol industry (667 million liters of ethanol per year). Alternatively, molasses as by-product of cane sugar industry (3 million tons per year) can be also used, but at only a surplus of 1.5 million tons (for 375 million liters of ethanol per year). It is likely that the highest annual production of ethanol without interrupting

other current industries is approximately 1,042 million liters. Consequently, the Ministry of Agriculture and Cooperatives has to adjust the National production policy since 2009 (Table 6) to promise the availability of raw material to ethanol industry.

5 Development of ethanol industry and its impact

5.1 Development of ethanol industry as the raw materials for other downstream industries

The role of ethanol will be increased as the solvent and the raw materials for production of other chemical derivatives. The chemicals derived from ethanol can be classified into 3 groups regarding types of reaction:

(1) Derivatives from dehydration: The significant one is ethylene, which is the raw material for making polyethylene and polyvinyl chloride.

(2) Derivatives from oxidation or dehydrogenation: The importance one is acetaldehyde, which is the raw material for making acetic acid and its derivatives such as butanol for making 2-ethyl hexanol using as the PVC plasticizer.

(3) Derivatives from modification: The importance one is chloroform.

The development of ethanol utilization in chemical industries will be very importance as it can be value addition.

5.2 Development of ethanol as fuel

The major consumption of ethanol is as fuel by mixing with 95 octane gasoline to be in a blend called gasohol. The National Ethanol Committee has to push the licensed manufacturers starting their production as soon as possible.

5.3 Use of fuel ethanol

To promote the use of ethanol as fuel, the blend of ethanol with 91 octane gasoline will be another alternative. This can lead to a reduction of gasoline consumption in the country.

5.4 Impacts of fuel ethanol industry on other industries

5.4.1 Impact of ethanol industry on cassava industry

The major cassava industries are cassava chips, cassava pellets and cassava starch industries, which use fresh cassava roots as the raw materials. In 2001, a total production of cassava roots is 18.40 million tons with a total 6.92 million Rais of planting area. A total demand of fresh cassava roots can be estimated from the production capacity of export cassava chips, cassava pellets, cassava starch and conversion ratio of each product (the amount of fresh cassava roots used to produce one unit of product). The estimation of cassava roots demand is summarized in Table 7.

Table 7 Demand of cassava roots in chips & pellets and starch industries as estimated by 3-years moving average.

Unit : Ton

Year	Demand of fresh cassava roots		
	For current industry	For ethanol industry	Total demand of fresh roots
2546[3/]	18,577,196	856,500	19,433,696
2547[3/]	18,718,382	1,498,875	20,217,257
2548[3/]	18,860,641	2,141,250	21,001,891
2549[3/]	19,003,981	2,141,250	21,145,231
2550[3/]	19,148,411	2,141,250	21,289,661

Table 7 demonstrates the trend of cassava roots demand for current industry and ethanol industry. The estimation is based on the assumption of 0.76% annual growth rate of cassava roots demand in current industry. The demand of fresh cassava roots for ethanol industry is estimated based on the assumption that the production is only 40% of total capacity in 2003 and then increases to 70 and 100% in 2004 and 2005, respectively, and remains unchanged afterwards. Under this circumstance, the total demand of fresh cassava roots will be increased from 19.43 million tons in 2003 to 21.29 million tons in 2007.

In order to prevent the impact of raw material consumption on other current industries, especially when the market demand of cassava chips and cassava pellet in EU is still unchanged, a certain policy on increasing the cassava roots supply for ethanol industry should be developed. Recently, in a workshop on "Strategic planning for sustainability development of cassava" established by Ministry of Agriculture and Cooperatives, The Thai Tapioca Development Institute and other relating agencies, a total productivity of cassava roots has been targeted to be increased from 17.3 million tons in 2002 to 26.8 million tons in 2006 or by 2.375 million tons each year. This can generate the surplus of fresh cassava roots (around 4 million tons) for ethanol industry. Yet, by 2010, the strategic planning has to be adjusted to ensure increasing cassava roots productivity corresponding to increasing ethanol production as shown in Table 6.

5.4.2 Impact of ethanol industry on sugar cane and cane sugar industries

The sole industry using sugar cane is cane sugar industry. This industry consumes around 59.99 million tons of cane and produces around 3.0 million tons of molasses with a domestic demand only 1.5 million tons. Therefore, the use of surplus molasses (1.5 million tons) for ethanol production will increase the value of sugar industry by-product without any impact on the domestic consumption. However, to prevent the impact on liquor industry, the amount of used molasses and produced ethanol should be considered and defined according to the situation of liquor and ethanol production.

5.4.3 Impact of ethanol industry on the nation economics

To promote the using of gasohol (E10, a blend of 10% anhydrous ethanol with 90% gasoline (91 octane or 95 octane)), an incentive of the excise tax privilege of ethanol part is approved. The excise tax for gasoline is 3.685 Baht/liter. When excluding the excise tax of ethanol (10% is equal to 0.3685 Baht/liter), the excise tax of gasohol is only 3.165 Baht/liter. With this policy, the government revenue will be reduced by 1,689 million Baht in 2003 and by 2,080 million Baht in 2007. However, the import value of crude oil will be saved by 5,227 and 6,481 million Baht in 2003 and 2007, respectively.

6. Recommendations

(1) The ethanol industry still has a lot of opportunity especially when used as fuel ethanol, as an alternative petroleum fuel, which has to import from aboard.

(2) The production and trading of ethanol are controlled by the government. This limits the development of ethanol industry. If the market mechanism as used in fuel ethanol can be implemented with the beverage ethanol, this will be benefit for developing the ethanol industry.

(3) The government should take a role in both supply and demand of ethanol. The government should have the action plan on ethanol supply to ensure the market demand. Meanwhile, the government should promote the market demand such as the tax privilege in order to extreme the supply capacity.

(4) To develop the ethanol industry as fuel ethanol, there should be planing of raw material management especially cassava chips and molasses to prevent the material shortage and high price situation.

(5) Since ethanol is very important raw material for other downstream industries, there should be developing ethanol utilization in other chemical industries as well as fuel purpose to be benefit to the country's economics in long term.

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