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An Assessment of the Biofuels Industry in Thailand*

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*The views expressed in this paper are those of the author and do not necessarily reflect the views of the United Nations.

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Summary

Thailand, with its abundant agricultural resources, is well positioned to effectively deploy biofuels – ethanol and biodiesel – in helping meet its energy needs. The Thai Government has formulated a two- phase gasohol (gasoline-ethanol blend) programme. In Phase 1 (2004-2006), in addition to the three ethanol plants currently operating, three others are scheduled to come on-stream by the end of 2006, and this will increase the production capacity to 1.155 million litres/day. For Phase 2 (2007-2012), the Government awarded licences to 18 new biodiesel plants, and this will bring the total installed capacity to 3 million litres/day by 2012. Of the 18 new plants in Phase 2, 14 will use molasses as feedstock and the remaining four will be cassava-based. Thailand's gasoline demand is estimated to be 30 million litres/day by 2012, and so there will be sufficient ethanol for blending in E10 gasohol (10% ethanol in gasoline) to meet the entire national daily demand (27 million litres of regular gasoline plus 3 million litres of ethanol). By 2012, the 91 octane regular gasoline will be replaced by E10 gasohol, which has an octane rating of 95. The Government is providing the necessary infrastructure for ethanol blending and gasohol distribution.

The sustained availability of feedstock (sugarcane/molasses, cassava) for ethanol manufacture is of critical importance to the success of the gasohol programme. Thailand is by far the largest producer of sugarcane in South-East Asia. Sugarcane production peaked at 74.3 million tons in 2003 but fell to 65.0 million tons in 2004 and 49.6 million tons in 2005 owing to drought conditions. Even so, the sugar produced (5 million tons in 2005) is greatly in excess of domestic requirements (about 2 million tons annually), and so Thailand is a major exporter of sugar and molasses. Through the allocation of a portion of the sugarcane grown to direct ethanol manufacture, the ethanol production capacity can be further increased. Thailand is well positioned to become the dominant ethanol producer in Asia.

Thailand is Asia's largest producer of cassava, with an average output of 20 million tons a year. After domestic consumption and export requirements have been met, about 4 million tons are available annually; and at a conversion rate of 6 kg cassava root per litre of ethanol, this will yield 1.8 million litres of ethanol per day.

The biodiesel industry is in its infancy in Thailand but is poised for rapid growth. Diesel consumption is currently at 50 million litres/day and is expected to rise to 85 million litres/day by 2012. The Government plans to have an installed biodiesel production capacity of 8.5 million litres/day by 2012 so that B10 (10% biodiesel in diesel) can meet the national diesel requirements. A key element of the Government's strategic plan for biodiesel is plantation development for the vegetable oil crops to be used as feedstock – palm oil and Jatropha. Palm oil is the world's most productive vegetable oil crop, and being the northern neighbour of the world's largest palm oil producer, Malaysia, Thailand has the right climatic and soil conditions for large-scale palm cultivation. The Government plans to develop palm plantations totalling 4 million Rai (0.7 million hectares), which will yield 4.8 million litres/day of biodiesel. In addition, palm plantations covering 1 million Rai in area will be developed in a neighbouring country, most likely Malaysia, and this will lead to an additional biodiesel production capacity of 1.2 million litres/day. Finally, the Government plans to cultivate more palm and Jatropha to bring biodiesel production to 2.5 million litres/day, as a result of which the total daily biodiesel production will be 8.5 million litres by 2012.

The Government has created an enabling environment for biofuels development. The National Biofuels Committee is responsible for policy direction, strategy planning and

implementation. It is supported by the ministries of finance, agriculture, industry and energy. Financing and project development mechanisms have been set up through Special Purpose Vehicles (SPV) and financial institutions for successful project implementation. By 2012, the ethanol and biodiesel programmes will save the national economy $325 million and $675 million, respectively, each year.

General background

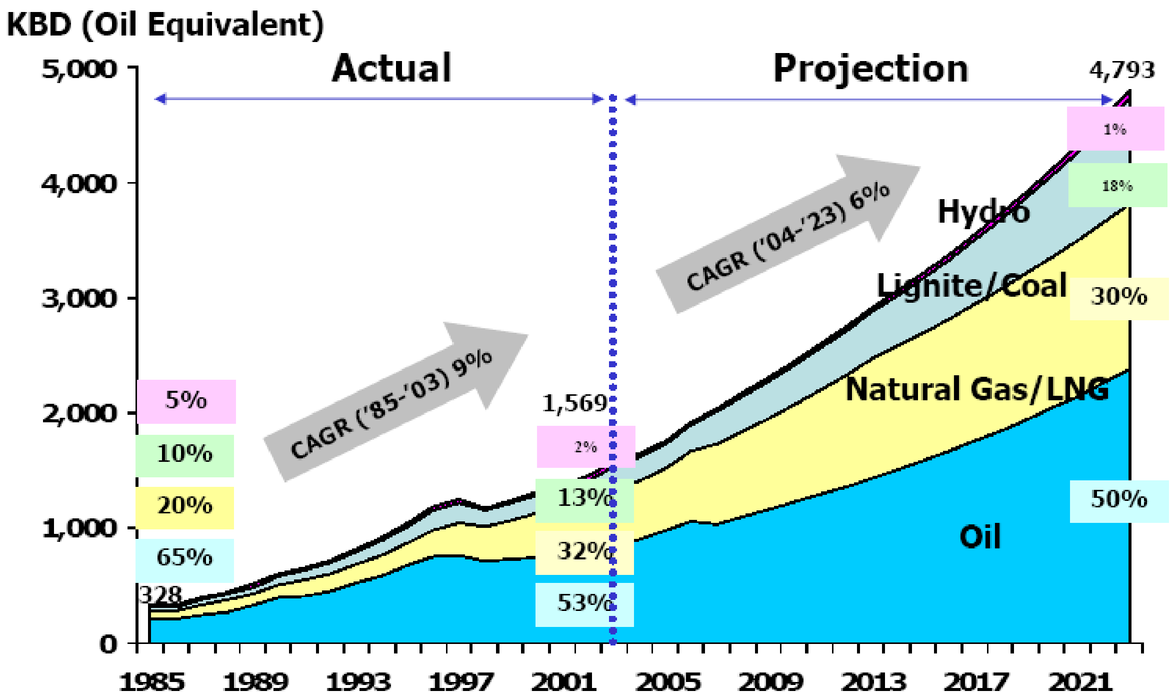
Thailand's economy has slowed slightly over the past year, but real GDP growth was reasonably strong at 6.3% in 2004, down from 6.8% in 2003. During 2004, slower growth in Thai exports was partially offset by a strong year in the tourism sector. Real GDP growth for 2005 was 5.7%. Longer-term annual growth rates are projected to be in the range of 5%-6%.[2]

The Thai economy is burdened by a relatively weak banking sector with a high proportion of non-performing loans. Also, delays in the restructuring of corporate debt have been worrisome enough to prompt warnings from the International Monetary Fund (IMF) and international credit rating analysts. Any worldwide economic downturn could rapidly affect Thailand because of these structural weaknesses.

Thailand's energy sector is undergoing a period of restructuring and privatization. The Thai electric utility and petroleum industries, which historically have been State-controlled monopolies, are currently being restructured.

Demand for energy in Thailand has increased tremendously over the years.[3] From 1999 to 2003, gasoline consumption nationwide increased from 7,024 million litres to 7,632 million litres while diesel consumption increased at an even faster pace, from 15,303 million litres to 17,562 million litres. Figure 1 shows the growth in Thailand's energy demand.

Figure 1. Growth in Thailand's energy demand



Source: Choopiban (2005).

[2] US Department of Energy (2005).
[3] Rabobank International (2005).

In addition, Thailand's net fuel imports more than doubled, from $3,530 to $7,908 million, and this has entailed the loss of a great deal of foreign currency. In 2003, petroleum productsI imports accounted for 6.64 % of Thailand's GDP. The Thai Government has realized that the country is over-reliant on imported energy and has initiated a renewable energy policy to investigate alternative sources of energy such as solar, wind, water and biofuel energy. Today, the introduction of biofuel energy, which is energy generated from plant and animal sources, is a high priority in national policy.

Biofuels in Thailand consist of ethanol and biodiesel. Ethanol is produced by the fermentation of molasses, a by-product of sugar manufacture. Typically, one ton of sugarcane yields about 45 kg of molasses, out of which 10 litres of ethanol can be produced. Although this is not normally done in Thailand, the sugarcane juice can all be directly utilized in fermentation to ethanol, and one ton of sugarcane yields 70 litres of ethanol. Another feedstock for ethanol manufacture is cassava, also known as tapioca. This root contains 25% starch. The starch is first hydrolysed to sugar, which is then fermented to ethanol.

Ethanol is blended in gasoline (petrol) and this mixture is called gasohol. Gasohol containing 10% ethanol is referred to as E10. Brazil uses ethanol as 100% fuel in about 20% of petrol-powered vehicles and a 22 to 26% ethanol-petrol blend in all other vehicles. The United States and Australia use E10.

Biodiesel, manufactured by the transesterification of vegetable oil, can be similarly blended with diesel to reduce the consumption of diesel from petroleum. A 10% blend of biodiesel in diesel is called B10. Biodiesel production is rapidly growing in Europe and the United States. It is currently estimated to be about 2.2 Mt/year in Europe,[4] with Germany (1,088,000 t/year), France (502,000 t/year) and Italy (419,000 t/year) being the leading producers. The European Union has mandated that biofuels consumption, as a percentage of total fuel consumption, should be at least 2% for its members by 2005 and 5.75% by 2010. Biodiesel production is about 245,000 t/year in the United States.

The Thai Government plans to have sufficient capacity for the production of ethanol (3 million litres/day by 2011) and biodiesel (8.5 million litres/day by 2012), so that by 2012, E10 and B10 will completely meet Thailand's petrol and diesel requirements. Use of 3 million litres/day of ethanol will reduce the import bill by 13 billion Baht/year ($325 million/year). Likewise, the 8.5 million litres/day of biodiesel represents a savings of 27 billion Baht/year ($675 million/year).

Ethanol industry

Status of ethanol manufacture and utilization in Thailand

There are currently three ethanol plants in Thailand, with a total output of 0.375 million litres/day. Three more plants are scheduled to come on-stream by 2006, and this will increase the capacity to 1.155 million litres/day. Table 1 gives more details about these plants.

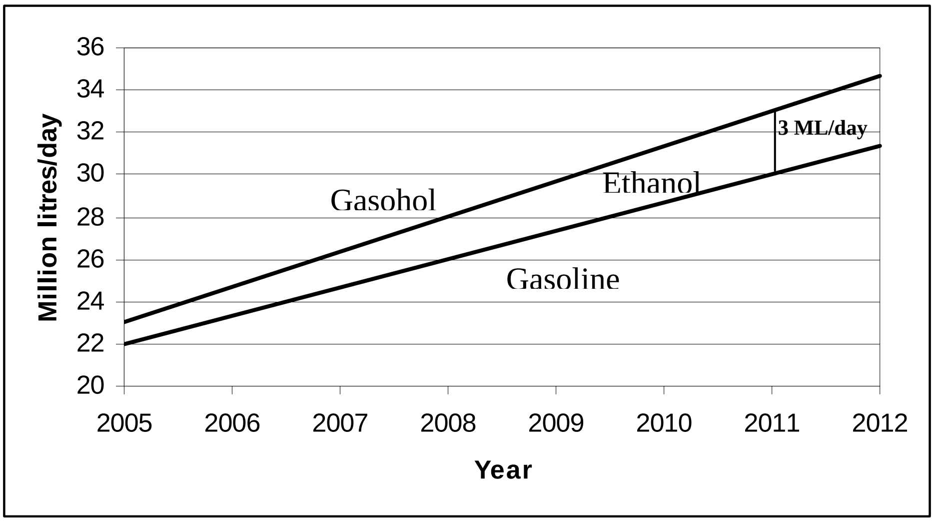
[4] Garofalo (2004).

Table 1. Ethanol plants: Current progress				
Manufacturer	**Capacity, litre/day**	**Raw material**	**Province**	**Start date**
Pornvilai International Group	25 000	Molasses	Ayuthaya	Oct. 03
Thai Alcohol	200 000	Molasses	Nakornpatom	Aug. 04
Thai Agro Energy	150 000	Molasses	Supanburi	Feb. 05
Thai Nguan Ethanon	130 000	Cassava	Konkaen	Nov. 05
International Gasohol Corporation	170 000 330 000	Cassava	Rayong	Dec. 05 Dec. 06
Konkaen Alcohol	150 000	Molasses	Konkaen	Dec. 05

Source: Sajjakulnukit (2005).

Figure 2 shows the gasoline and ethanol supplies. Note that the gasohol supply is the sum of the gasoline and ethanol supplies.

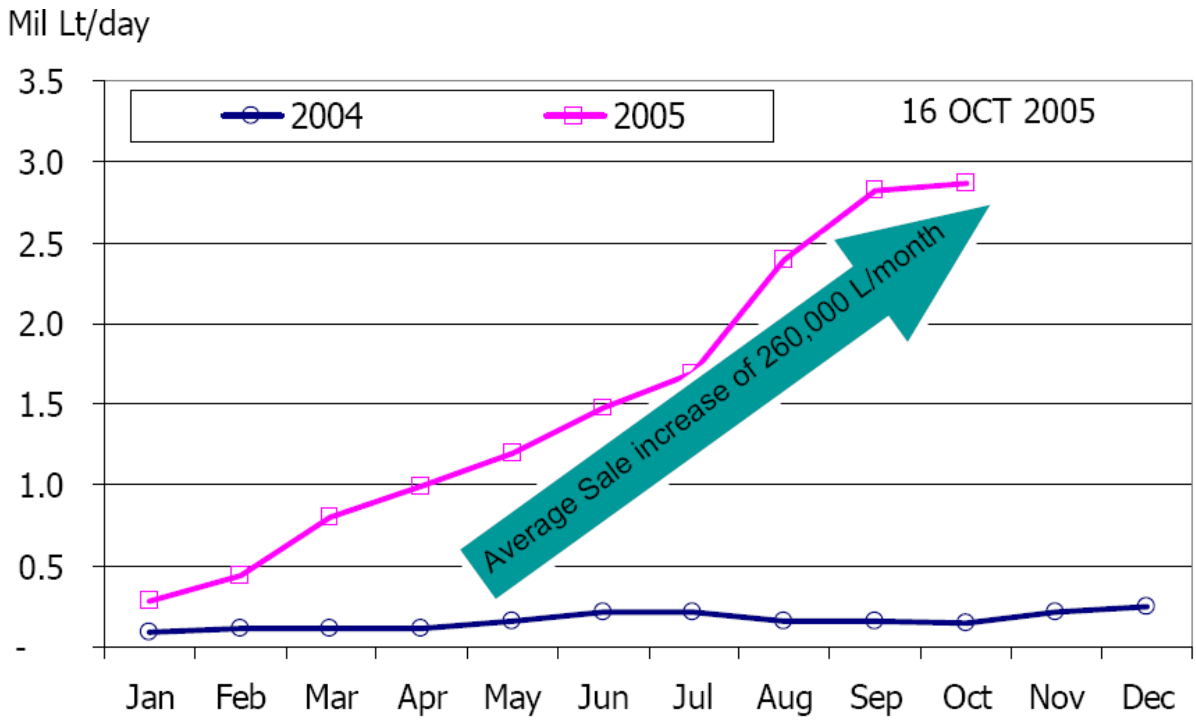
Figure 2. Projected gasoline and ethanol supplies in Thailand



Source: Sajjakulnukit (2005).

Figure 3 shows the sales of gasohol for 2004 and 2005. Note that gasohol has 10% ethanol. The overall average demand for gasoline was about 22 million litres/day.

Figure 3. Sales of gasoline and ethanol in 2004 and 2005



Source: Sajjakulnukit (2005).

Gasohol Strategic Plan

The Gasohol Strategic Plan developed by the Ministry of Energy consists of two phases:

Phase I (2004-2006)

- Ethanol production will increase to 1.155 million litres/day when three more plants come online.
- MTBE will be phased out and no longer used in unleaded gasoline.
- The Government will develop specifications for Gasohol 95 (91 octane gasoline + 10% ethanol, equivalent to E10) and perform emission tests on engines running on it. Ethanol (octane number of 120) is an octane enhancer, and blending it with 91 octane gasoline increases the octane number of the gasohol to 95, hence the classification Gasohol 95.
- The Government will mandate that all of its vehicles use gasohol.
- The Government will formulate policies on the use of gasohol in high-performance vehicles.

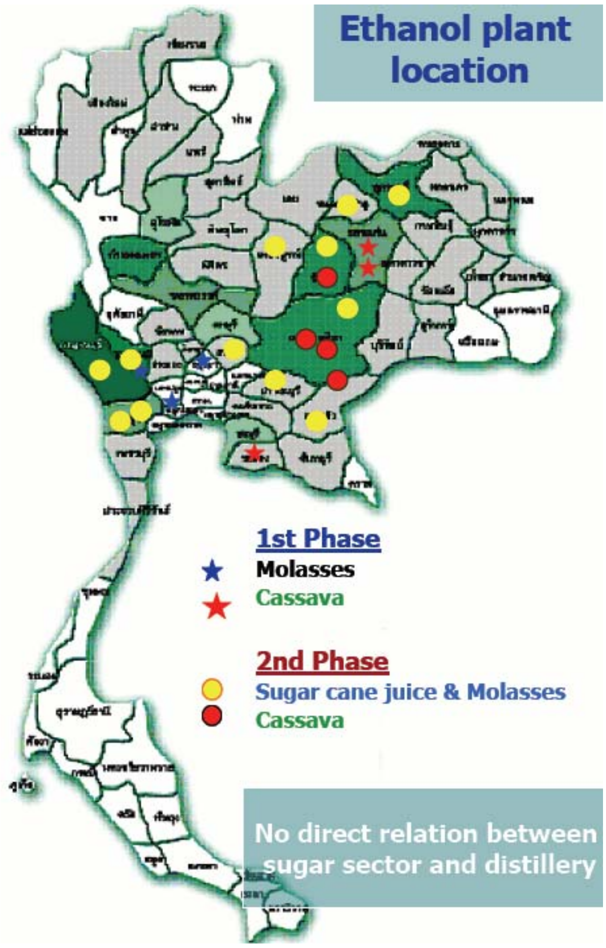
Phase II (2007-2012)

- Ethanol production will increase to 3.0 million litres/day by 2011. The Government has already granted licences to 18 new ethanol plants with a nameplate capacity of

3.65 million litres/day. Out of these 18 plants, 14 will be based on molasses and 4 on cassava.

- By 2012, all petrol consumed will be Gasohol 95 by law.

Figure 4. Location of current and planned ethanol plants



Source: Sajjakulnukit (2005).

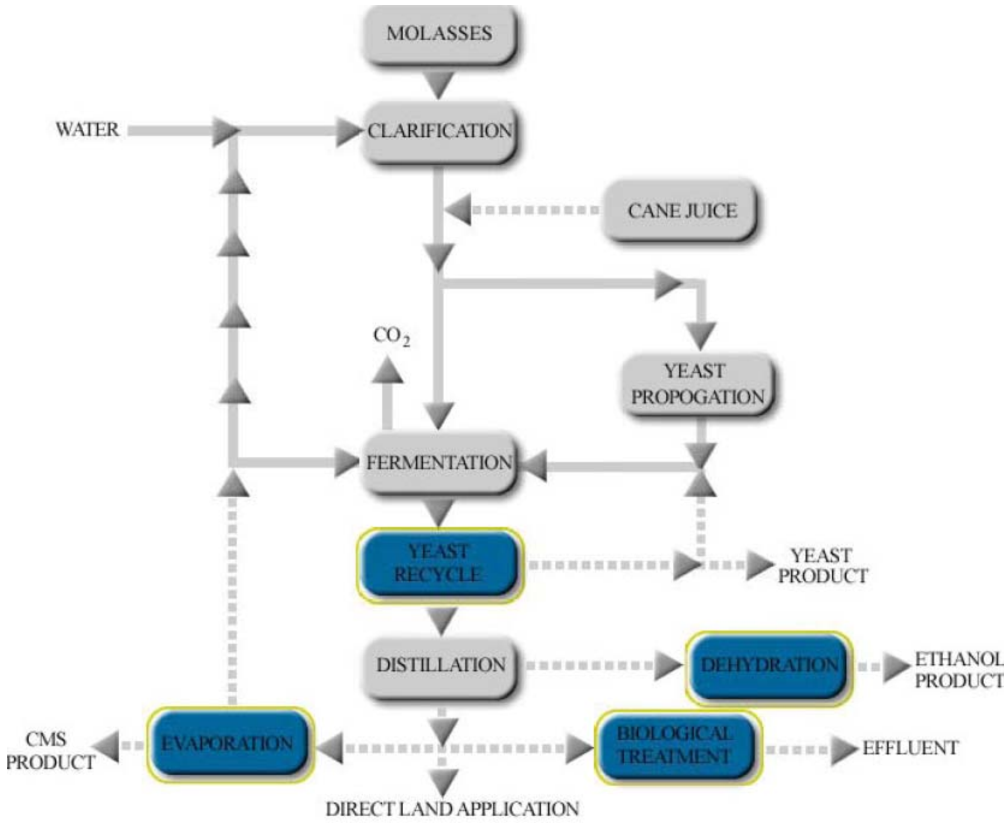
Ethanol manufacture from molasses

Molasses, a thick, black, viscous liquid, is the by-product of sugar manufacture from sugarcane, and has a high sugar content. It is fermented under the action of yeast to produce ethanol, as represented by the following reaction:

$$\underset{\text{Sugar}}{C_6H_{12}O_6} \rightarrow \underset{\text{Ethanol}}{2C_2H_5OH} + \underset{\text{Carbon dioxide}}{2CO_2}$$

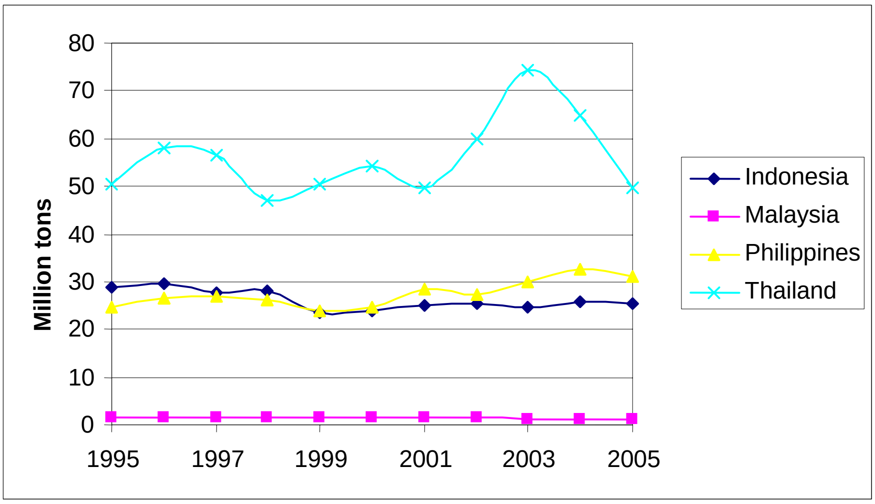
This ethanol is actually a 10% solution of ethanol in water. It is distilled to produce anhydrous alcohol (99% ethanol purity). Special techniques (e.g. azeotropic distillation, extractive distillation, molecular sieve/pressure swing adsorption, membrane separation) are used to get past the azeotropic point (95% ethanol concentration). The process flow diagram is shown in figure 5.

Figure 5. Process flow diagram for manufacture of ethanol from molasses



Sugarcane cultivation in Thailand and price swings

Figure 6. Sugarcane production in Thailand and other countries in the region



Source: Food and Agriculture Organization, Agriculture Database.

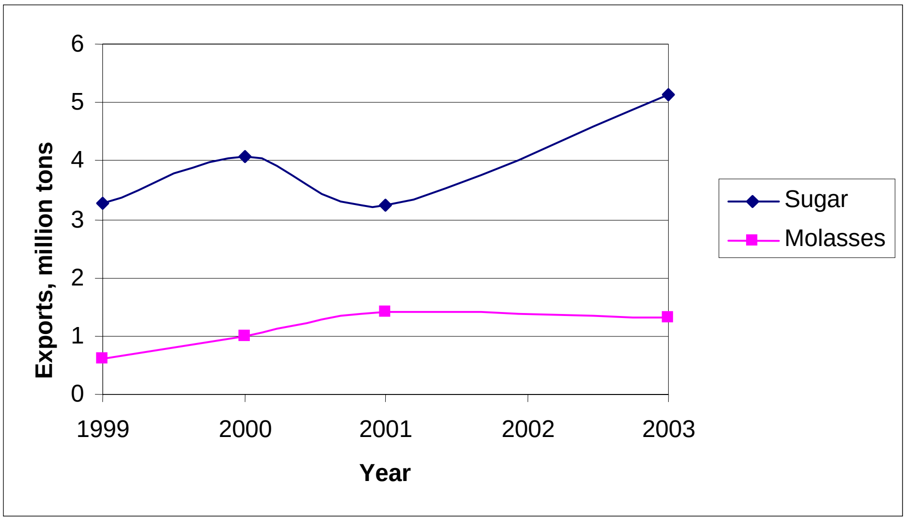
Figure 6 shows that Thailand is by far the largest producer of sugarcane in South-East Asia. Sugarcane production peaked at 74.3 million tons in 2003 but fell to 65.0 million tons in 2004 and 49.6 million tons in 2005. The reason for the drop is the continuing drought.[5] About 85% of the sugarcane cultivation lands are rain-fed. Sugarcane production is expected to fall further to 40 million tons in 2006.

As a result of falling sugarcane production, the price of sugarcane and molasses has gone up. The Government-fixed ex-factory sugarcane price per ton increased from Baht 465 ($11.63) in 2004 to Baht 820 ($20.5) in 2006. The exchange rate is approximately Baht 40 to 1 US dollar. The price of molasses per ton shot up from Baht 1,000 ($25) in 2004 to Baht 3,200 ($80) in 2006.

The Government has set sugar prices by providing price supports. The current wholesale price of sugar is Baht 11.77 ($0.29) per kg. There have been calls to increase the sugar price by Baht 2.00 in order to reduce the financial burden on the Government's sugar and cane fund. The Government has also set the ethanol price at Baht 12.75 ($0.32) per litre. The optimum molasses price level for this ethanol price would be Baht 1,800 ($45) per ton as against the current market price of Baht 3,200 ($80) per ton. As a result, ethanol output fell, and the Government allowed ethanol imports of 18 million litres from India to meet the ethanol demand during September-December 2005.

Government policy to increase ethanol production

Figure 7. Exports of sugar and molasses from Thailand



Source: United Nations Commodity Trade Database.

Given that Thailand's domestic sugar consumption is about 2 million tons a year, figure 7 charts the sugar produced in excess of this consumption, which is ultimately exported. For instance, in 2003, Thailand produced 7.2 million tons of sugar and about 5.2 million tons was exported. The Government is considering reducing sugar exports by allowing up to 26 million tons of sugarcane cultivation per year to be diverted to ethanol manufacture. Thus, instead of 2.6 millions tons of sugar being earmarked for sugar exports, 26 x 70 = 1,820

[5] US Department of Agriculture (2005).

million litres a year of ethanol (5 million litres/day) would be available for blending with gasoline.

The Government has to come to an agreement with ethanol producers on how to distribute earnings from the sales of ethanol manufactured directly from sugarcane juice. Currently, the earnings from sugar are divided 70:30 – 70% to the growers of sugarcane and 30% to the sugar millers. The ethanol producers now want more than 30% of the proceeds as they have to make capital investments in ethanol plants.

The Government is also thinking of banning the exports of molasses and using this supply as feedstock for ethanol manufacture. Thailand normally exports about 1.3 million tons of molasses (excluding the recent drought-related sugarcane shortage); and at a conversion rate of 250 litres of alcohol per ton of molasses, this represents 328 million litres annually.

Thailand plans to become a major ethanol producer and export centre. Asian economies such as Japan, China, the Republic of Korea and India represent a major ethanol demand. Japan is importing 300-400 million litres of ethanol a year and will increase this to 600 million litres. Instead of exporting relatively low-valued commodities such as sugar and cassava chips, Thailand can profit by converting sugarcane and cassava to ethanol.

Ethanol manufacture from cassava

Cassava contains 25% starch. In starch molecules, the glucose (sugar) molecules are separated by α 1-4 linkages. Enzymes such as amylase break these linkages, thus converting starch to sugar in a process called saccharification. The sugar is then fermented, as in the molasses processes, to produce ethanol. In the new processes, saccharification and fermentation take place at the same time – simultaneous saccharification and fermentation (SSF). Figure 8 is a schematic diagram of ethanol manufacture from potatoes. An identical procedure is used for cassava since it is a starchy root like potato.

Figure 8. Ethanol production from starchy material

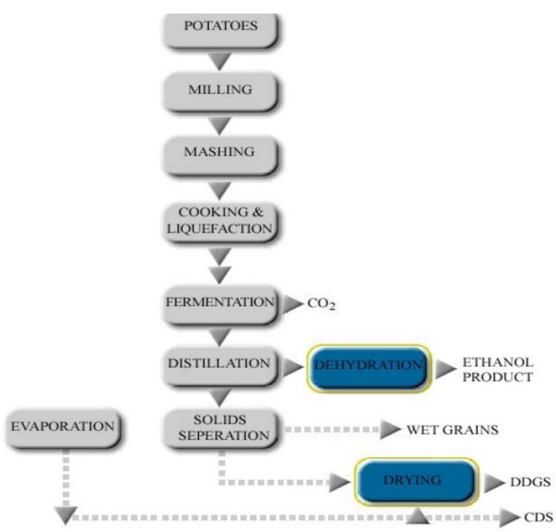
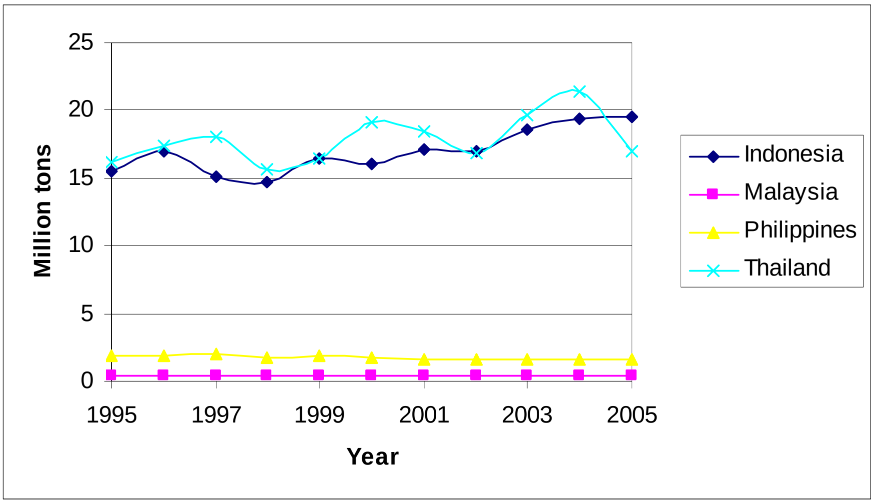


Figure 9 shows cassava production in South-East Asia.

Figure 9. Cassava production in Thailand and neighbouring countries



Source: Food and Agriculture Organization, Agriculture Statistics Database.

For effective ethanol production, dried cassava chips are recommended as feedstock because:

1. Chips can be produced by farmers during the peak of the harvesting season (when the root price is lowest).
2. Chips can be stored and used when roots are not harvested.
3. Chips can effectively be transported to the ethanol plant.
4. Chips can be used to produce ethanol by advanced processes such as simultaneous saccharification and fermentation (SSF) as used with grains to minimize production cost.

Thailand is Asia's largest producer of cassava. With the exception of the drought year of 2005, Thailand's average cassava root production is 20 million tons a year. About 8 million tons of cassava roots are used for domestic starch consumption. Another 8 million tons are used for making cassava chips for export. The remaining 4 million tons/year can be used for ethanol, and at a conversion rate of 6 kg cassava root per litre of ethanol, this will yield 1.8 million litres per day. If the 8 million tons for export are used instead for ethanol production, an additional 3.6 million litres/day is available.

Cost of ethanol plants

A study by Thai Oil PCL,[6] one of the nation's largest refiners, resulted in a cost estimate of $150-$200 million for a cassava-based ethanol plant with a capacity of 1-2 million litres per day. Taking the mid-point of both the cost estimate and plant capacity, a 1.5 million litre a day plant, based on cassava, will cost $175 million in Thailand. For other capacities, the cost is estimated using the power law:

($C \propto V^{0.6}$ where C is the cost and V the plant capacity)

[6] Thai Oil PCL (2005).

Thus, if the capacity in the base case, V_0, is 1.5 million litre/day, and the base cost, C_0, is $175 million, the cost, C, in millions of dollars, will be:

$$C = C_0 (V/V_0)^{0.6}$$

$$C = 137.209 V^{0.6}$$

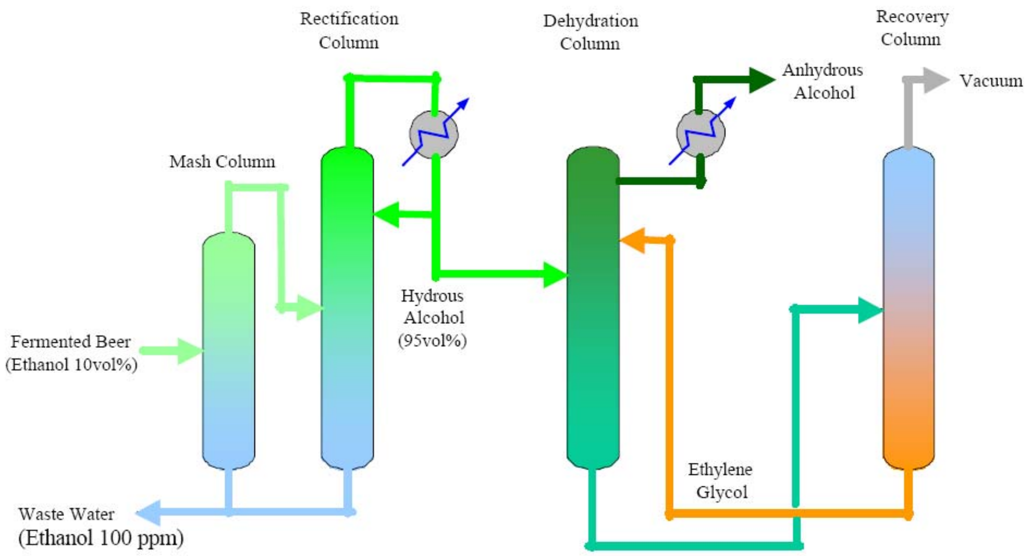
Table 2 gives the cost estimate for various plant capacities based on the above equation:

Table 2. Estimation of ethanol plant capital costs

Capacity, million litre/day	Estimated cost, $ million
0.1	34.5
0.2	52.2
0.3	66.6
0.4	79.2
0.5	90.5

The most important cost component of an ethanol plant is the distillation section, where fermented alcohol (10% ethanol, 90% water) is concentrated to anhydrous ethanol (99% ethanol). Figure 10 shows a typical distillation scheme for dehydrating ethanol.

Figure 10. Distillation scheme for dehydrating ethanol



Research and development in ethanol manufacture

Described below are some of the research projects at the cutting edge of ethanol technology.

Use of enzymatic fermentation of cellulose for ethanol manufacture[7]

Lignocellulosic materials such as straw and wood, which are often available as wastes, are much cheaper than sugarcane or cassava. Converting them to ethanol, however, requires complex and costly processes. The development of exciting new technologies has made it possible for lignocellulosic materials to become economic as ethanol feedstocks. The raw material is first pre-treated at 150-200^{o}C with steam or acid/alkali to dissolve some of the hemicellulose. Then enzymes called cellulase and hemicellulase are added to convert the cellulose and hemicellulose to fermentable sugars in a process known as hydrolysis. Finally, newly developed yeast strains are introduced to ferment the sugars to ethanol.

Improved methods of producing anhydrous ethanol

Fermentation produces a 10% solution of ethanol in water. For use as a fuel, this solution has to be concentrated to 99.8% ethanol (anhydrous) for blending with petrol. Just distilling an aqueous solution of ethanol gives a 95% ethanol solution. This is an azeotropic solution, and any further regular distillation does not increase the concentration of ethanol because in an azeotropic solution the composition of the vapour is the same as that of the liquid. A 95% ethanol solution can be used as a straight fuel. For producing anhydrous ethanol, the following processes are used:

- Azeotropic distillation;
- Extractive distillation;
- Pressure swing adsorption (PSA) based on molecular sieves;
- Membrane separation.

The first two methods are more commonly used and represent older technologies. PSA/molecular sieve technology is an efficient process for anhydrous ethanol. The 95% ethanol solution is vaporized and sent through a bed of molecular sieves at high pressure. Ethanol is adsorbed on the molecular sieves, and water passes through. On reducing the pressure, the ethanol is desorbed from the sieves and recovered as anhydrous ethanol. The Kon Kaen ethanol plant, based in Kon Kaen province in north-east Thailand, was commissioned in September 2005 with a capacity of 85,000 litres/day. One of the technical features of the plant is the use of molecular sieve technology for ethanol dehydration. Project proponents have applied for Clean Development Mechanism (CDM) status, hoping to gain CDM income that would help defray some of the capital expenses.

Membrane separation[8] is another efficient process. The membrane consists of a zeolite with a pore size of 0.4 nanometre (nm, 10^{9} metre). The ethanol molecule is 0.45 nm in size and gets trapped in the membrane, while the water molecule passes through since its size is 0.25 nm. The ethanol is recovered from the membrane pores.

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[7] Risoe National Laboratory, Denmark (2004).
[8] Goel (2004).

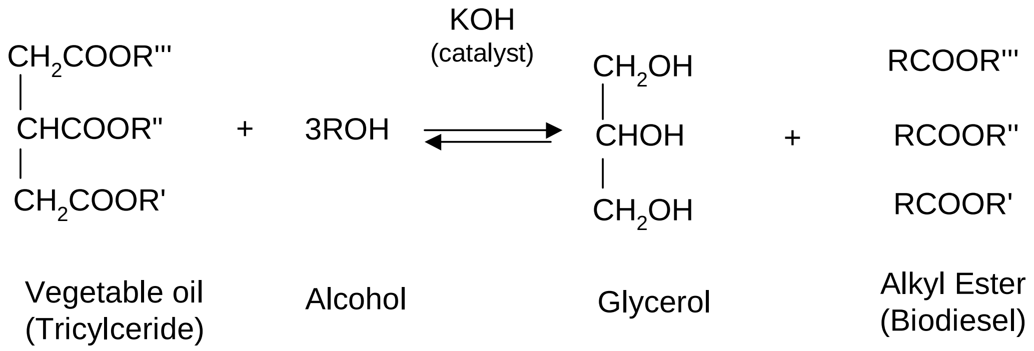
Improved agricultural practices[9]

The following are some of the improved agricultural practices that can be used to increase yield:

- Bio-pest control;
- Bio-fertilizer;
- Drought management practices for sugarcane;
- Ring pit method;
- Use of quality seed;
- Integrated weed management.

Biodiesel industry

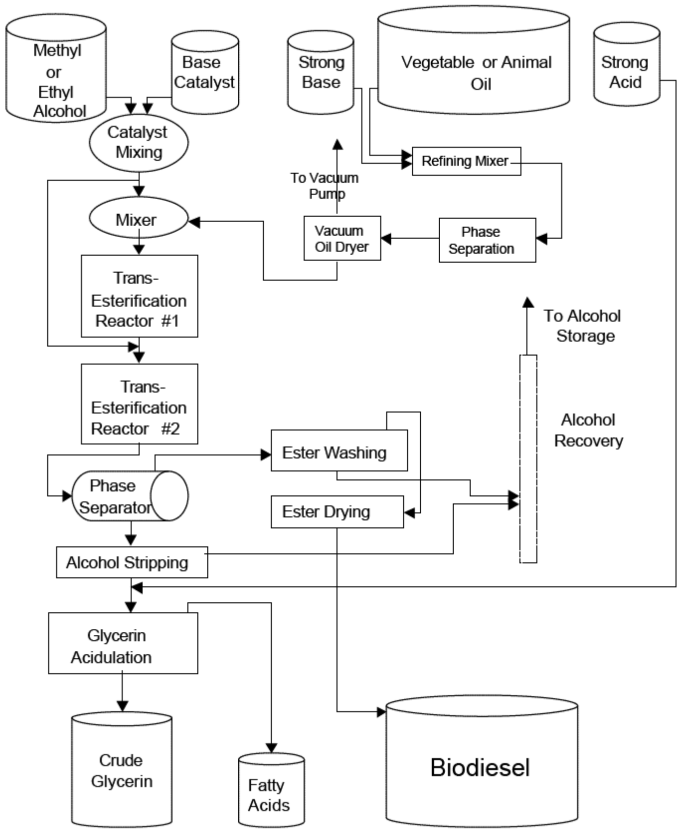
The most economical process for biodiesel manufacture is transesterification of vegetable oil by an alcohol, usually methanol. The most commonly used vegetable oils are soybean, canola (rapeseed), palm, sunflower and peanut. The chemical reaction is shown below, and is commonly catalysed by an alkali such as potassium hydroxide.



[9] Singh (2004).

Figure 11 gives the flowsheet for the manufacture of biodiesel.

Figure 11. Flowsheet for biodiesel manufacture via transesterification



Raw material for biodiesel manufacture in Thailand

The two main oilseed crops for biodiesel manufacture in Thailand are palm and Jatropha.

Palm oil

A hectare of palm oil, which is known to be the most productive oil crop, can produce 4 to 5 tons of crude palm oil. This is 5 to 10 times more than the yield of any commercially grown oil crop. Palm oil is extracted from the mesocarp (fleshy part) of the palm fruit. The largest producers of palm are Malaysia and Indonesia, accounting for 80% of the world's output. Thailand is increasing its palm oil production, as shown in table 3.

Table 3. Palm oil production (metric tons)

	1995	1996	1997	1998	1999	2000	2001	2002
Indonesia	4 479 670	4 898 658	5 385 458	5 902 178	6 555 000	7 276 000	8 015 000	9 020 000
Malaysia	7 810 546	8 385 890	9 068 730	8 319 680	10 553 920	10 842 100	11 804 000	11 909 300
Thailand	370 000	400 000	449 796	475 042	570 000	525 000	620 000	590 000

Source: Food and Agriculture Organization, Agriculture Statistics Database.

Palm oil has about 50% saturated acid (mainly palmitic acid – $C_{16}H_{32}O_2$). This leads to unacceptably high values for cold filter plugging point (+11^{o}C) and cloud point (+9^{o}C), which prevent winter operation on neat biodiesel from palm oil. Moreover, the high content of free fatty acids in the feedstock causes problems in traditional alkali-catalysed biodiesel production and thus necessitates de-acidification or acid-catalysed pre-esterification steps. But the main advantages of palm oil are outstandingly high hectare yields and moderate world-market prices compared with other edible vegetable oils, so that production of biodiesel from palm oil makes economic sense.

Jatropha oil

Jatropha oil is obtained from Jatropha curcas oilseed, a tree-borne oilseed originally developed in Central America, which grows in dry, arid land. Although Jatropha oilseed is not yet cultivated on a large scale in Thailand, Jatropha oil is the major feedstock of the biodiesel programme in India and other tropical countries.

Advantages of using Jatropha curcas[10]

- The oil yield per hectare for Jatropha is among the highest for tree-borne oil seeds. The seed production ranges from about 0.4 tons per hectare per year to over 12 t/ha. There are reports of oil yields of as high as 50% from the seed. Typically, the seed production would be 3.75 t/ha, with an oil yield of 30-35%, giving a net oil yield of about 1.2 t/ha.
- Jatropha can be grown in areas of low rainfall (200 mm per year), on low-fertility marginal, degraded, fallow, waste and other lands such as along canals, roads and railway tracks, on borders of farmers' fields as a boundary fence/hedge in the arid/semi-arid areas and even on alkaline soils.
- Jatropha is easy to establish in nurseries, grows relatively quickly and is hardy.
- Jatropha seeds are easy to collect as they are ready to be plucked before the rainy season and as the plants are not very tall.
- Jatropha is not browsed by animals.
- Being rich in nitrogen, the seed cake is an excellent source of plant nutrients.

Properties of Jatropha oil

The component analysis[11] of Jatropha seeds (wt%) is as follows: moisture 6.2%, protein 18%, fat 38%, carbohydrate 17%, fibre 15.5% and ash 5.3%. Jatropha oil mainly consists of tri-glycerides[12] of oleic acid (34-45%), linoleic acid (31-43%) and palmitic acid (14-15%).

Other oil feedstocks for biodiesel

Other oil feedstocks for biodiesel include peanut oil, coconut oil and used fatty frying oil.

[10] Planning Commission, Government of India (2003, p.111).
[11] Pramanik (2005).
[12] Mittelbach and Remschmidt (2004, p.26).

Status of biodiesel in Thailand

Large-scale commercial production of biodiesel has not yet begun in Thailand. A pilot-scale 150 litre/day biodiesel unit has been set up for research purposes. On the community scale, there are biodiesel plants with capacities ranging from 5,000 to 20,000 litres/day that serve communities in 11 provinces. These plants use used frying oil and crude palm oil as feedstock. Table 4 shows the provinces that have community-serving biodiesel plants.

Table 4. Current community-scale biodiesel production in Thailand

Province	Biodiesel capacity (litre/day)
Bangkok	20 000
Nakorn Rachasima	7 000
Chiangmai, Chonburi	5 000
Samutprakarn, Nonthaburi, Kon Kaen, Chiangrai, Ubonratchathani, Nakorn Srithammarat	28 000
Total: 11 provinces	**60 000**

Source: Sajjakulnukit (2005).

On 11 June 2005, the Government launched a demonstration project for biodiesel production from wasted cooking oil in Chiang Mai, a major city in the north of Thailand. It is the first demonstration project for biofuel production at the community level in Thailand and the first of its kind in Asia. The trial blending ratio of biodiesel is 2%, known as "B2", and the application targets 1,000 public passenger pick-ups running in the city. The blending of biodiesel will increase to 5% in 2007 and to 10% in 2012.

There are currently two proposed biodiesel projects applying for CDM status:

1. The first is the Japanese Transport Cooperation Association (JTCA) 300 ton/day (100,000 ton/year or 110 million litre/year) biodiesel plant. The feedstock will be 124,000 ton/year of crude palm oil, which will be extracted from 733,000 ton/year of palm fruit (fresh fruit bunch). The palm oil crop will be grown on plantations covering an area of 250,000 Rai (about 40,000 ha) in the southern province of Suratthani, which is close to Malaysia and three neighbouring provinces. The biodiesel plant will be located in Bangkok. The capital cost is estimated at $20 million. With an ex-factory biodiesel price of 20 Baht per litre ($0.50/litre), the annual sales revenue is estimated at $55 million.

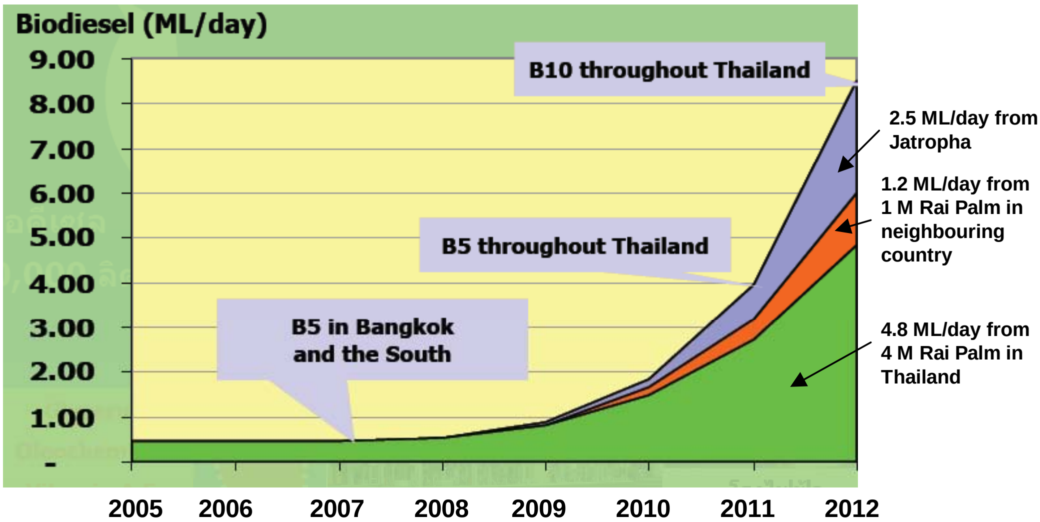
2. The second is the 15,000 ton/year biodiesel plant proposed by Japan-based Sun Care Corp. The feedstock will be sunflower oil harvested from 22,500 ha of sunflower plantation, which will yield 45,000 ton/year of sunflower oil seeds. The plantation will be located at Phu Rua in the northern province of Loei, which borders the Lao

People's Democratic Republic. The biodiesel plant will be located near the provincial capital of Loei.

Thailand's biodiesel strategy

The Government has formulated a strategy to ensure that by 2012 all the diesel sold in Thailand will be 10% biodiesel (B10). The Government will follow a phased approach. By 2007, diesel with 5% biodiesel (B5) will be introduced in Bangkok and the south. By 2011, B5 will be extended throughout the country. Finally, B10 will become mandatory nationwide by 2012, as shown in figure 12.

Figure 12. Planned introduction of biodiesel blend in Thailand



Source: Sajjakulnukit (2005).

The Government estimates that by 2012 about 85 M litres/day of diesel blend will be required in order to satisfy the demand in Thailand. Assuming that the blend is 10% biodiesel (B10), the biodiesel requirement would be 8.5 M litres/day by 2012. The Government will invest 1.3 billion Baht ($32.5 million)[13] between 2005 and 2012 to achieve a biodiesel production of 8.5 M litres/day by 2012.

Development of feedstock plantations for biodiesel

A key component of the biodiesel strategy is the development of palm and Jatropha plantations, which can be divided into three distinct areas:

1. Development of domestic palm plantations covering a total area of 4 M Rai (0.67 M ha). The Rai is the unit of area measurement in Thailand and is roughly equal to one sixth of a hectare. The yield of palm oil based biodiesel is 1.2 litre/day from a 1 Rai palm plantation. Thus, a 4 M Rai plantation will provide 4.8 M litre/day of biodiesel.

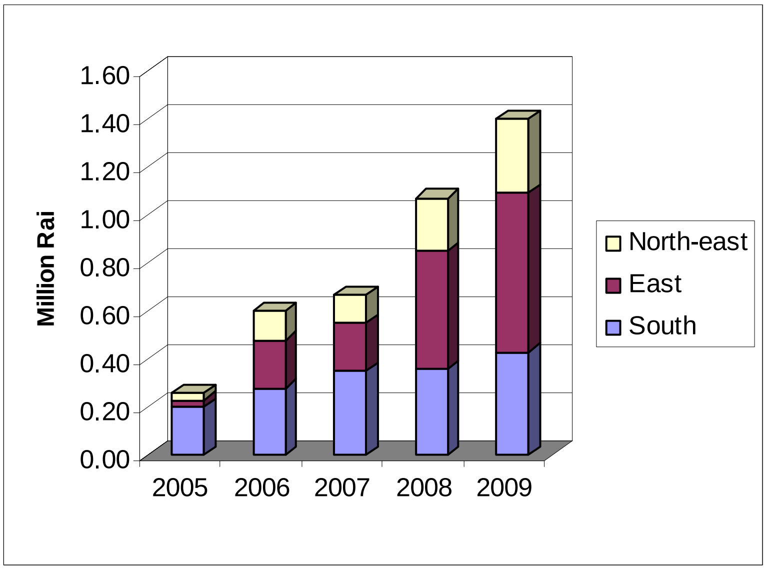
[13] Thienpaitoon (2005).

2. Development of palm plantations covering a total area of 1 M Rai in a neighbouring country. This would yield an additional 1.2 M litre/day of biodiesel. Thailand is bordered by Viet Nam, the Lao People's Democratic Republic and Malaysia. Malaysia, the world's largest producer of palm oil, will most likely be the neighbouring country to develop the 1 M Rai palm plantation for Thailand.

3. Development of Jatropha and palm plantations to produce a further 2.5 M litre/day. If the Jatropha oilseed yield is 1.2 ton/Rai/year, the biodiesel yield will be 1.1 litre/day/Rai. Jatropha plantations with an area of 1 million Rai and palm plantations with an area of about 1.2 million Rai will provide 2.5 million litre/day biodiesel.

A total investment of 70 billion Baht ($1.75 billion) is required for developing the plantations.

Figure 13. Planned domestic cultivation of palm for biodiesel



Source: Sajjakulnukit (2005).

Figure 13 shows the phased development of palm plantations in the south, east and north-east for the 4 M Rai cultivation. The south is closest to Malaysia; it has the most suitable climatic conditions for palm cultivation and will therefore be the first area for palm cultivation. The Government will develop the eastern region next. The North-east has a more temperate climate and is more suited for crops such as sunflower.

Installation of biodiesel plants

A typical biodiesel plant will have a capacity of 300 ton/day (0.33 M litres/day). Thus, about 26 such plants will be needed to provide 8.5 M litres/day of biodiesel. With a capital cost of $20 million per plant, the total investment will be $520 million.

Table 5. Operating cost of 330,000 litre/day biodiesel plant

	Units per litre of biodiesel	Unit cost, $	Cost per litre of biodiesel, $
Feedstock, refined palm oil (kg)	0.900	0.470	0.4230
Methanol (kg)	0.097	0.149	0.0145
Alkali catalyst (kg)	0.001	0.127	0.0002
Power (kWh)	0.026	0.075	0.0020
Steam (kg)	0.680	0.013	0.0090
Cooling water (m^3)	0.004	0.078	0.0003
Wash water (m^3)	0.000	0.131	0.0000
Fuel oil (litre)	0.038	0.215	0.0081
Sales and administration	1.000	0.010	0.0100
Employee costs			0.0174
Maintenance 2.5% of cap. cost ($0.1818/litre)			0.0045
Insurance 1% of cap. cost ($0.1818/litre)			0.0018
Total per litre before int., dep. & gly. credit			0.4909
Glycol credit (kg)	0.092	0.220	0.0203
Total per litre after gly. credit		0.470	0.4706
Int. & dep. 16% of cap. cost ($0.1818/litre)			0.0291
Total cost per litre after int., dep. & gly. credit			0.4997
Total cost per litre in Baht (@ 40 Baht per $)			20.00 Baht/lit.

Source: Independent Business Feasibility Group (2002).

Table 5 shows that the ex-factory cost of biodiesel is 20 Baht per litre ($0.50 per litre). This compares very favourably with petroleum diesel.

The capital cost of biodiesel plants for various capacities is shown in table 6.

Table 6. Capital cost of biodiesel plants

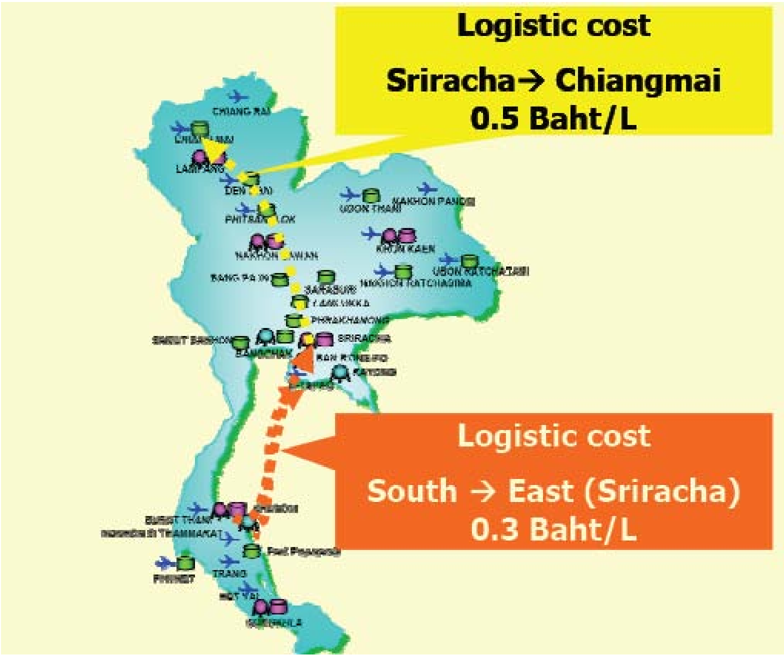
Biodiesel plant capacity, litres/day	Lower limit, $ million	Upper limit, $ million
10 370	1.90	3.10
31 110	3.60	6.00
51 849	4.90	8.20
77 774	6.30	10.50
103 699	7.50	12.50
155 548	9.50	15.80
207 397	11.40	19.00
311 096	14.50	24.10
518 493	19.70	32.80

Source: Independent Business Feasibility Group (2002).

Logistical cost of transporting biodiesel for blending

Biodiesel must be transported from the factory to the blending plant, where it is blended with petroleum diesel. The biodiesel factory is generally located near the plantation –for example, in the southern province or in Chiang Mai in the north. The blending facility would be in Sriracha, the centre of Thailand's petroleum refining industry.

Figure 14. Logistical cost of transporting biodiesel to blending site



Source: Sajjakulnukit (2005).

Figure 14 shows the logistical cost of transporting the biodiesel from the plants in Chiang Mai and the south to the blending facility in Sriracha. From the south to Sriracha, the transport cost is 0.3 Baht/litre (1.5% of the ex-factory cost of biodiesel), and from Chiang Mai to Sriracha it is 0.5 Baht/litre (2.5% of the biodiesel cost). Transport from the south is mainly over water and a shorter distance; hence the transport cost is lower when compared with that from Chiang Mai. Overall, the added cost due to transporting the biodiesel to the blending facility is not significant.

Research and development in biodiesel manufacture

Research efforts in biodiesel are focused on the areas described below.

Improvements in yields of oil seed crops

Table 5 shows that 85% of the biodiesel cost is attributable to the cost of feedstock. Research efforts are focusing on improving the yield of oil seed crops. The aim is to increase the yield of palm fresh fruit bunch (FFB) from 2.7 ton/Rai/year to 3.3 ton/Rai/year. This will increase the biodiesel production from 1.01 to 1.23 litre/Rai/day. Similarly, efforts are under way to increase the yield of Jatropha oilseeds from 0.4 to 1.2 ton/Rai/year. This would triple the biodiesel output from 0.37 to 1.11 litre/Rai/day.

Increased efficiency in refining palm oil

Oil extracted from palm fruit is crude palm oil. The oil has to be refined, and the free fatty acid content has to be reduced to less than 0.05 wt% before the refined oil can be transesterified to produce biodiesel. Newer processes using ultra-low pressure distillation of crude palm oil are very efficient.

Novel methods such as hydrocracking and hydrotreating

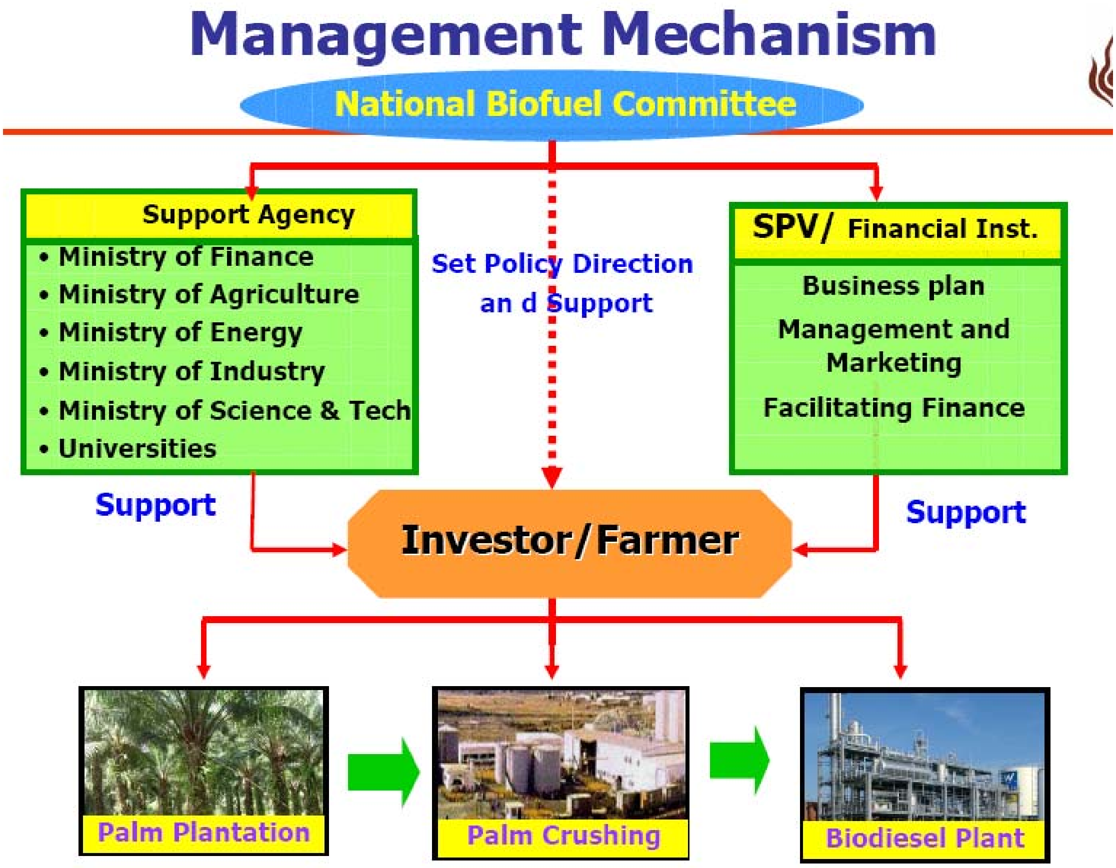
These processes break down the triglyceride molecules in vegetable oil to produce biodiesel molecules without using transesterification. Advantages of this process include the following:

(a) methanol and the alkali catalyst are not required; (b) refining of the crude palm oil is now not needed; in fact, even the free fatty acids are cracked to biodiesel; and (c) glycerol is not produced as a by-product and hence its disposal is no longer a concern. These methods require high pressure and hydrogen, but this can easily be handled at a petroleum refinery.

Enabling environment for biofuels

The Thai Government has created an environment that enables biofuels development. The National Biofuel Committee is the central agency for developing and implementing the biofuels strategic plan. As shown in figure 15, support is provided by key government ministries such as finance, agriculture, industry and energy. Research and development is co-coordinated through the ministry of science and technology and the national universities. Equally important are the financing and project development mechanisms set up through Special Purpose Vehicles (SPV) and financial institutions for successful project implementation.

Figure 15. Management and support structure for biofuels



Source: Sajjakulnukit (2005).

Conclusions

Thailand, with its abundant agricultural resources, is well positioned to effectively deploy biofuels, namely ethanol and biodiesel, to help meet its energy needs. The Thai Government has formulated a two-phase gasohol (gasoline-ethanol blend) programme. In Phase 1 (2004-2006), three additional ethanol plants will be brought on-stream by year-end 2006, with the production capacity being increased to six plants producing up to 1.155 million litres/day. For Phase 2 (2007-2012), the Government awarded licences to 18 new biodiesel plants, and this will bring the total installed capacity to 3 million litres/day by 2012. Of the 18 new plants in Phase 2, 14 will use molasses as feedstock and the remaining four will be cassava-based. It is estimated that national gasoline demand will be 30 million litres/day by 2012. There will be sufficient ethanol for E10 gasohol blending to meet the entire national daily demand (27 million litres of regular gasoline plus 3 million litres of ethanol). By 2012, the 91 octane regular gasoline will be replaced by E10 gasohol, which has an octane rating of 95. The Government is providing the necessary infrastructure for blending ethanol and distributing gasohol.

The sustained availability of feedstock (sugarcane/molasses, cassava) for ethanol manufacture is of critical importance to the success of the gasohol programme. Thailand is by far the largest producer of sugarcane in South-East Asia. Sugarcane production peaked at 74.3 million tons in 2003 but fell to 65.0 million tons in 2004 and 49.6 million tons in 2005 owing to drought conditions. Even so, the sugar produced (5 million tons in 2005) is greatly in excess of the domestic requirements (about 2 million tons annually), and this makes Thailand a major exporter of sugar and molasses. Through the allocation of a portion of the sugarcane grown to direct ethanol manufacture, the ethanol production capacity can be greatly increased. Thus, from 26 million tons of sugarcane, an additional 1,820 million litres/year (5 million litres/day) can be produced. Thailand can become the dominant ethanol producer in Asia, providing ethanol to meet Japan’s needs (500-600 million litres/year) and also those of the rapidly growing economies of China and India.

Thailand is Asia’s largest producer of cassava, with an average annual output of 20 million tons. About 4 million tons are available annually after domestic consumption and export requirements have been met; and at a conversion rate of 6 kg cassava root per litre of ethanol, this will yield 1.8 million litres per day. If the 8 million tons for export is used instead for ethanol production, an additional 3.6 million litres/day will be available.

The biodiesel industry is in its infancy in Thailand but is poised for rapid growth. Diesel consumption is currently at 50 million litres/day and is expected to rise to 85 million litres/day by 2012. The Government plans to have an installed biodiesel production capacity of 8.5 million litres/day by 2012 so that B10 (10% biodiesel in diesel) can meet the total national diesel demand. A key element of the Government’s strategic plan for biodiesel is the development of vegetable oil crop, palm oil and Jatropha plantations for feedstock. Palm oil is the world’s most productive vegetable oil crop, and being the northern neighbour of the world’s largest palm oil producer, Malaysia, Thailand has the right climatic and soil conditions for large-scale palm cultivation. The Government plans to develop palm plantations with a total area of 4 million Rai (0.7 million hectares), which will yield 4.8 million litres/day of biodiesel. In addition, the Government will develop palm plantations covering 1 million Rai in a neighbouring country, most likely Malaysia, and this will add 1.2 million litres/day of additional biodiesel production capacity. Finally, Jatropha and some more palm cultivation are planned; this will result in 2.5 million litres/day of biodiesel and thus increase the total biodiesel production to 8.5 million litres a day by 2012.

The Government has created an enabling environment for biofuels development. The National Biofuels Committee is responsible for policy direction, strategy planning and implementation. It is supported by the ministries of finance, agriculture, industry and energy. Financing and project development mechanisms have been set up through Special Purpose Vehicles (SPV) and financial institutions for successful project implementation. By 2012, the ethanol and biodiesel programmes will save the national economy $325 million and $675 million, respectively, each year.

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