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GREATER MEKONG SUBREGION
ECONOMIC COOPERATION PROGRAM

STATUS AND POTENTIAL FOR THE DEVELOPMENT OF BIOFUELS AND RURAL RENEWABLE ENERGY

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AND RURAL RENEWABLE ENERGY

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Abbreviations

BAAC	–	Bank of Agriculture and Agricultural Cooperatives
CPO	–	crude palm oil
GDP	–	gross domestic product
GMS	–	Greater Mekong Subregion
ktoe	–	thousand tons of oil equivalent
Lao PDR	–	the Lao People’s Democratic Republic
LPG	–	liquefied petroleum gas
MOAC	–	Ministry of Agriculture and Cooperatives
MOE	–	Ministry of Energy
PRC	–	the People’s Republic of China

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Introduction

For half a century, Thailand has been involved in experiments to convert oil crops into biofuel, to help provide a replacement to finite fossil fuels. His Majesty the King foresaw the possibility of heavy reliance on oil imports, and initiated these efforts. However, progress was rather slow, because the price of imported fuel was at a historic low. When oil prices started to rise in 2003, Thailand realized that the period of cheap oil could be over. The rise in oil prices, together with a number of political and economic factors, spurred the government to formulate and adopt a national program that would address the emerging energy crisis that could threaten economic growth and destabilize the nation's economy. The most rational candidate for an alternative source of energy was biofuel, taking into consideration Thailand's strong agricultural base and its surplus production of oil crops that are suitable for biofuel production.

However, the development of biofuels has not been easy. Selected biofuel crops have competing uses such as food and feed, in addition to fuel. Moreover, the demand for these crops is, to a large extent, dependent on developments in the export markets. An increase in domestic demand for feedstock can adversely affect the domestic food market and the export market. Furthermore, it has been difficult to attract investments in biofuel production without offering a number of incentives to both growers and biofuel producers. These incentives include price guarantee schemes and lower levies or taxes, and the formulation of built-in flexibility to make the price of biofuel competitive with fossil fuel. These policy incentives pose serious challenges, particularly to policy makers, but they need to be addressed to facilitate biofuel development and dampen the ill effects of fluctuating oil prices.

The drafting and implementation of the National Energy Policy were relatively straightforward. It was only when the program was in operation that loopholes and shortcomings were discovered, both in production and end use, particularly with reference to the automobile industry. Biofuel production did not increase to any appreciable extent, and in many instances, conflicts became apparent in the use of resources for food, feed, and fuel. The government agencies involved were so engrossed in the implementation of the policy and the national biofuel program that they were unaware of the emerging conflicts that would endanger food security. Only later did they realize that in order to achieve any degree of success, biofuel development must proceed in an integrated manner that involves all stakeholders.

The automobile industry was a critical stakeholder that was not initially receptive to the government's call for early adoption of biodiesel and gasohol to replace fossil fuels. The automobile manufacturers felt that, while they had to do something to avoid the destabilizing effect of spiraling oil prices, especially in 2006–2007, there were other measures to be taken before biofuels could be accommodated. Most critical was the need to adjust engine specifications to allow the use of biofuel. This called for further investment in engine modifications. Gasoline stations likewise required major physical alterations before they could offer the new fuels—biodiesel and gasohol.

The initial hindrances to biofuel production and use in Thailand were gradually overcome and the subsector is now developing rapidly. There is now a need to take stock of achievements and to analyze the bottlenecks. Adjustments will have to be made to the biofuel policy to make it fully effective and responsive to the country's rapidly increasing and wide-ranging demand for energy, while maintaining food security. Although the problem of food security is less serious in Thailand, a rise in demand for food could have spillover effects in neighboring countries which are net importers of food. The biofuels policy needs to achieve and maintain a delicate balance in order for it to be effective and sustainable.

The objectives of this study are to:

(i) identify promising areas for investment in the development of the biofuel subsector in Thailand, with due consideration of the country's location in the Greater Mekong Subregion (GMS);

(ii) evaluate possible implications for crop diversification, land use patterns, farm restructuring and cross-border contract farming, as a result of introducing a biofuel program in the GMS countries;

(iii) enhance appropriate public–private partnership to foster business ventures in biofuels; and

(iv) review current national policies and strategies on the development of bioenergy to identify recommendations that will further refine national strategies and strengthen the national biofuel program.

In this report, the section on Market outlook examines the trend in energy consumption and demand facing Thailand is examined. The section also forecasts the future demand for fuels, and the extent to which it can be met by internal supplies of limited oil and gas reserves and the expansion of biofuel areas. The next section describes the country's resource base and its potential for the production of biofuels. Attempts will be made to estimate the potential production of biofuel crops through better use of land and other resources. The situation of biofuel production will be analyzed. Biofuel producers can be large private companies or small, community-level investors. There is scope for improvements in technology, especially in small-scale industries. More funds will be needed in the near future to conduct research and to develop and apply technology in this field.

The latter part of the section discusses the prioritization of feedstocks for the purpose of expanding their supply to meet the biofuel production targets set by the government to replace a portion of petroleum imports. The section on biodiesel business options evaluates options available to stakeholders from the farm level to the final consumer. The community approach can provide a cushion against external risks, but may not be able to realize full economies of scale at the level currently enjoyed by large-scale biofuel refineries.

Even though Thailand has adopted a national biofuel policy, implementation remains a challenge; therefore, policy issues are identified and discussed in the penultimate section, entitled "Policy Support for Biofuels", the existing regulatory framework and institutional context are analyzed. The regulatory framework follows the energy conservation act, while the institutional setup stems from the act of the national energy commission. They cover all economic sectors, but for the purpose of this study, attention will focus only on biofuels. The success of biofuel interventions depends on the cooperation of the government, industry, the transport sector, and also biofuel crop producers and processors. In the long run, food security cannot be compromised; nevertheless, efforts must be continued to appreciably lessen dependence on petroleum imports. The section ends with a discussion of the pricing of ethanol and biodiesel.

The conclusions and recommendations presented in the final section are based on an assessment of the biofuel market and its potential in Thailand.

Market Outlook

Energy Consumption and Demand

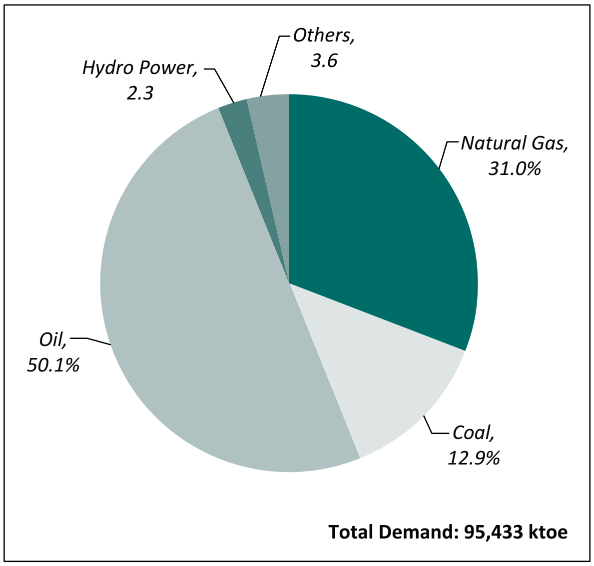
In Thailand, the primary sources of energy are the fossil fuels—crude oil and petroleum products, natural gas, and coal—and hydropower. The composition of the energy supply in 2006 (Figure 1) shows oil as the largest source, providing 47,820 thousand tons of oil equivalent (ktoe), or about 50% of the total supply.

Natural gas accounts for 31% of the total energy supply. Coal, used mostly for generating electricity and in the operation of heavy industries, contributes about 13% of the total supply (Figure 1).

The two economic sectors that account for the majority of energy consumption are industry (37.5%) and transport (36.3%) (Figure 2). Energy demand comprises petroleum products, electricity, coal, and natural gas. Petroleum products make up 60% of total energy demand because they are widely used in industry and transport. Electricity, comprising 21% of total energy demand, is consumed by households and businesses, and, to a lesser extent, by industry.[1]

During 2002–2006, Thailand's energy consumption increased from 1.28 million barrels of oil equivalent per day to 1.56 million barrels of oil equivalent

Figure 1: Composition of Primary Energy Sources, 2006 (%)

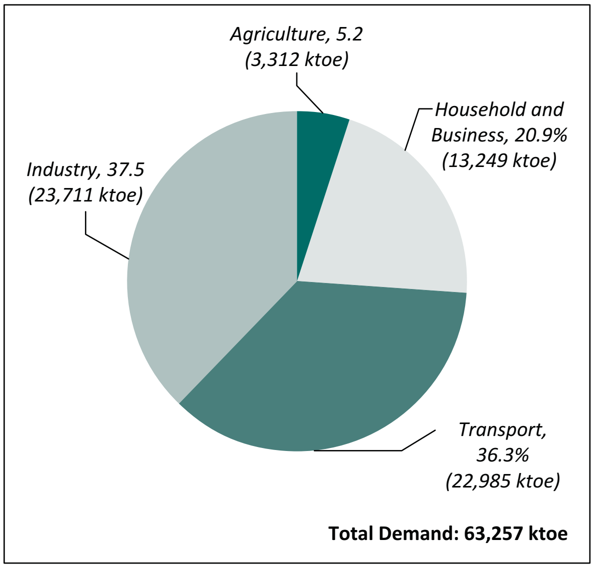


ktoe = thousand tons of oil equivalent.

Note: Percentages may not total 100% because of rounding.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

Figure 2: Final Energy Demand by Economic Sector, 2006 (%)



ktoe = thousand tons of oil equivalent.

Note: Percentages may not total 100% because of rounding.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

[1] Pongphirodom, P. 2007. *Perspectives on Energy Policy in Thailand.* Lecture note prepared by Department of Alternative Energy Development and Efficiency, Ministry of Energy, delivered at Mae Fah Luang University, Chiang Rai, Thailand. May, 2007.

per day (Table 1). Although domestic production increased during this period, oil imports also grew. The proportion of imports to consumption peaked in 2004, but remained a little over 60% throughout that period. Dependence on oil imports cannot be easily reduced, since economic growth requires an increasing supply of energy.

There has been a spectacular increase in the value of energy imports. The value of crude oil imports increased from baht (B) 287 billion ($6.67 billion) in 2002 to B750 billion ($19.77 billion) in 2006. This is equivalent to a yearly increase of nearly 50% in local currency. In 2002, the value of total energy imports, which included crude oil, petroleum products, natural gas, coal, and electricity, was B360 billion ($8.37 billion). It reached B912 billion ($24 billion) 5 years later, in line with the rate of growth of crude oil imports.[2]

Thailand imports natural gas mostly from Myanmar, and electricity from the Lao People's Democratic Republic (Lao PDR). Such trade relationships have important implications for the development of renewable energy resources—including biofuels—in the GMS.

The rise in the consumption and use of energy, and the consequent rise in energy import bills prompted Thailand to introduce nationwide energy-saving measures in 2003. In that year, the energy demand elasticity, measured as the ratio between growth in energy consumption and growth in gross domestic product (GDP), was 1.2. This means that for every 1% growth in GDP, energy demand would increase by 1.2%. In 2008, the elasticity was about 1.0. The energy elasticity targeted for 2011 is 0.85, i.e., the rate of growth in energy consumption would be 15% lower than the rate of growth of GDP. Based on the GDP forecast, this could amount to energy savings of as much as B177 billion ($4.99 billion) over the period 2008–2011 (footnote 1).

Government measures to achieve such a scenario include (i) energy management, which involves conducting a series of campaigns to provide the public with information on how to save energy in the transport sector and in the consumption of electricity nationwide; (ii) process improvement, which uses tax incentives and soft loans to modify and enhance the efficiency of processing plants and equipment; and (iii) the introduction of advanced information technology, for example in services, to reduce the amount of energy required. However, this is likely to materialize slowly as it requires the necessary software and skilled personnel to be in place. Much of the emphasis is therefore on demonstrating and disseminating knowledge to local investors and entrepreneurs on the adoption of information technology.

In 2003, renewable energy constituted only 0.5% of total energy consumption. With government efforts, coupled with the participation of the private sector and the public, it rose to 4% in 2006. A target of 8% has been set for 2011, of which 1% will come from power generation, 4% from heating, and 3% from transport. This will be achieved primarily through the use of biofuels. Power generation draws renewable energy from biomass, biogas, the wind, and solar

Table 1: Consumption, Production, and Imports in Thousand Barrels of Oil Equivalent per Day, 2002–2006 ('000 barrels)

Item	Oil Equivalent per Day ('000 barrels)				
	2002	2003	2004	2005	2006
Consumption	1,351	1,351	1,450	1,500	1,557
Production	671	671	676	743	770
Imports	868	868	988	980	974
Imports divided by Consumption (%)	64	64	68	64	63

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy. 2007.

[2] Figures are from the Department of Alternative Energy Development and Efficiency, Ministry of Energy. The dollar figures in brackets have been converted from the baht at the exchange rate prevailing in the year referred to.

sources, which in 2006 provided 2,061 megawatts (MW) and is projected to increase to 3,251 MW in 2011. The heat process, as practiced by industry, will use 3,851 ktoe of renewable energy supplies from biomass and biodiesel produced from used cooking oil in 2011, increasing from 1,856 ktoe in 2006.

The government aims to increase the use of ethanol from 0.4 million liters per day (l/day) in 2006 to 3.0 million l/day by 2011. The target for biodiesel is 4.0 million l/day in 2011, from only 0.1 million l/day in 2006. These renewable energy consumption targets constitute the market outlook for biofuel development in Thailand.

Ethanol Demand

Since transport consumes more than a third of the country's energy requirements, the government has introduced alternatives to fossil fuels in this sector. Sources of power such as electricity and hydrogen can be used to run automobile engines, but these hybrid cars are still at the experimental stage and therefore cost much more than conventional vehicles. Liquefied petroleum gas (LPG) is widely available and is obtained from natural gas plants. It is commonly used for household cooking, and it can be easily retrofitted in gasoline vehicles, with minimal adjustments to the engine. However, the demand for LPG exceeds the domestic supply and must be met by gas imports. Natural gas for vehicles—also known as compressed natural gas—is regarded as a clean form of energy when used in cars. However, it is not available throughout the country, due to the lack of an extensive pipeline system.

The biofuel policy was adopted to meet the energy needs of the automobile industry and to find other uses for excess energy crops produced in the country. Competition in resource allocation between food and feedstock has not been a significant factor, as Thailand is persistently a major net food exporter to the rest of the world.

With the introduction onto the market in Thailand of gasohol 91 and gasohol 95,[3] the demand for gasoline in the form of benzene 91 and benzene 95 is projected to decrease between 2008 and 2011.[4] This is due partly to the government's regulation of the blending of gasoline, and partly to the government's insistence on pricing differentials between gasoline and gasohol, which have widened from B1.50/l ($0.05) to B4.00/l ($0.13). Even gasohol 95 is cheaper than benzene 91, providing an added incentive to consumers. Thus by 2011, the demand for benzene 91 and benzene 95 is expected to diminish (Table 2). The level of demand for benzene 95 is expected to fall from 0.99 million l/day to 0.72 million l/day between 2008 and 2011. Benzene 91 will cease to be used by 2011, and gasohol 95 will increase from 8.89 million l/day to 9.50 million l/day during the same period. Correspondingly, the demand for gasohol 91 will nearly quadruple in 4 years, to 12.02 million l/day.

Initially, the raw materials for ethanol production will come mainly from the sugar mill by-product, molasses. Some ethanol plants in Thailand are owned by sugar mills. In the past, alcohol in the beverage industry was produced from molasses under a tightly controlled government monopoly, according to the 1950 law on alcoholic beverages. Since molasses is a by-product of the sugar industry, and the opportunity was open to produce alcohol—a product in high demand overseas—it is therefore not surprising that sugar mills were the first group of investors when the ethanol industry was liberalized. However, the ethanol produced could only be sold for automobile use. When gasohol was introduced, ethanol sales did not pick up, and this created a huge excess of supply in the country. When ethanol producers complained, the cabinet granted private distillers exclusive permission to export ethanol on a case-by-case basis.

Sugar production, and hence the production of molasses, has remained stagnant. Since 80% of cassava produced is usually exported, the government projects a steady increase in domestic cassava

[3] Gasohol 91 is gasoline (or benzene) with 91 octane content, and gasohol 95 is a gasoline (or benzene) with 95 octane content. Both are blended with 10% ethanol, replacing first, methyl tertiary butyl ether and then the gasoline itself.

[4] Department of Alternative Energy Development and Efficiency, Ministry of Energy.

Table 2: Demand for Benzene and Gasohol, 2008–2011

Item	Unit	Quantity Demanded			
		2008	2009	2010	2011
Benzene 95	million l/day	0.99	0.89	0.80	0.72
Gasohol 95	million l/day	8.89	9.05	9.21	9.50
Gasohol 95 (E20)	million l/day	0.25	0.58	0.90	1.23
Benzene 91	million l/day	7.63	5.69	3.57	0
Gasohol 91	million l/day	3.27	5.69	8.32	12.02
Total ethanol	million l/day	**1.27**	**1.59**	**1.93**	**2.40**
Feedstock					
Molasses	%	80	70	60	50
Cassava	%	20	30	40	50
Volume of Feedstock					
Molasses	million t/year	1.48	1.62	1.69	1.75
Cassava	million t/year	0.54	1.02	1.66	2.57

l/day = liters per day, t/year = tons per year.

Note: The conversion rate of molasses to ethanol is 250 liters per ton, and the conversion rate of cassava to ethanol is 170 liters per ton.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

consumption for conversion into ethanol. By 2011, it is expected that the proportion of ethanol produced from cassava will reach 50% (Table 2).

Demand for gasohol 95 E20 (gasohol 95 with 20% ethanol) is projected to rise to 1.23 million l/day in 2011. Meeting the demand for gasohol requires the production of 1.59 million l/day of ethanol in 2009, a figure which is projected to increase to 2.40 million l/day by 2011.

Biodiesel Demand

In Thailand, the vast majority of biodiesel is made from palm oil. Jatropha is being used on a small scale. Palm oil prices have fluctuated over time. Although in any given year Thailand has always been a net exporter of palm oil, in some months it has to import the commodity, partly to meet domestic demand and partly to re-export processed palm oil to other countries. To ensure a sufficient palm oil supply, the government has intervened by controlling prices, granting import permits to palm oil traders, and offering a price guarantee to plantation owners. The development of biodiesel will exacerbate this phenomenon.

It should be noted that much diesel is consumed for non-transport uses. Total demand for diesel was 55.6 million l/day in 2008 and is projected to increase to 62.7 million l/day by 2012 (Table 3). In the same period, the demand for pure biodiesel will almost triple from 1.16 million l/day to 3.14 million l/day. The increase is due to the government regulation stipulating that all diesel sold at gasoline stations must be blended with 2% biodiesel, known as B2. By 2011, B2 will be replaced by B5, or diesel mixed with 5% biodiesel. The government believes that there is sufficient lead time for the automobile industry to adapt to the changing conditions by 2011.

Table 3: Demand for Pure Biodiesel and Crude Palm Oil, 2008–2012

Item	Unit	2008	2009	2010	2011	2012
Diesel	million l/day	55.60	57.30	58.70	60.30	62.70
Total B100	million l/day	1.16	1.33	1.38	3.02	3.14
B100 for B5	million l/day	0.20	0.30	0.35	3.02	3.14
B100 for B2	million l/day	0.96	1.03	1.03	0.00	0.00
Total B100	million l/year	423.00	484.00	505.00	1,100.00	1,144.00
Total crude palm oil	million t/year	0.39	0.45	0.47	1.02	1.06

B2 = diesel blended with 2% biodiesel, B5 = diesel blended with 5% biodiesel, B100 = 100% biodiesel, l/day = liters per day, l/year = liters per year, t/year = tons per year.

Note: B2 will be phased out after 2010, and replaced by B5.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

Characterization and Potential of the Resource Base

Thailand's rich and diverse resources for agriculture have been the main springboard for the spectacular growth in this area. The poor tend to remain in agriculture, so this growth has uplifted the livelihoods of a substantial proportion of the rural population. In the past, agriculture expanded at the expense of forests. However, forestlands have been cleared to their limit, so further increases in production must come from the existing farmland.

Fortunately, Thailand's resource base extends across various farming activities, from staple foods such as rice and fish, to tropical fruits and vegetables. Aquaculture is very competitive and can be further developed, even within the existing level of knowledge. The poultry industry enjoys a level of technology that is generally competitive with the rest of the world. It has weathered the avian influenza crisis and other crises, and still remains strong.

Human resources—both technical and at the farm level—are the major factor underlying the successes of farming. Skilled training in secondary and tertiary education has produced an excellent human resource base with strong specialization in research and development. The income disparities between rural and urban areas have been a decisive factor in rural-to-urban migration and the expansion of the urban population. Rural-to-urban migration first appeared to be seasonal, but over time became permanent. Transport and communication advances brought about by the expansion of road networks, the mobile telephone revolution, and a host of modern facilities, have also encouraged members of the rural population to migrate to the cities. However, for those remaining in the rural areas, the drive to rise out of poverty, coupled with support from the government, has propelled farmers to improve their income through the use of improved seed varieties, fertilizers and irrigation, and better farm management practices. As a result, agriculture has emerged as a strong base for the economy, supported by public–private partnerships and entrepreneurialism among the farmers.

Crops for Biofuel Production

Crops for Ethanol Production

In Thailand, sugarcane, and cassava are the two main crops used to produce ethanol. They are available in large quantities, and in the past have mostly been exported. Other crops can be used to produce ethanol, but they are not economically viable and alternative uses offer higher returns. Maize is a major ingredient of animal feed in Thailand's livestock industry and cannot be easily replaced. Sweet sorghum has gained a dismal record in Thailand as an alternative feed crop, and its re-emergence as a bioenergy crop is unlikely.

The production of sugarcane has been limited by market prices. Sugar export prices in 2004–2005 were still relatively low, although the industry was successful in pushing up the controlled domestic prices after a series of failed attempts. In 2006, the price of sugar increased by nearly 40% from B12.50 per kilogram (/kg) ($0.33) to B17.00/kg ($0.45). In early 2008, the government allowed the price of sugar to rise further by nearly 30%. This caused hardship among consumers, who were already experiencing inflation in the price of a number of commodities. Two-thirds of the sugar produced is exported, but farmers do not want to expand the area under sugarcane because the world price is lower than the domestic price. Thus the supply of molasses is limited by the amount of feedstock produced.

Furthermore, the planted area for sugarcane has been stable at around one million hectares (ha) during 2005–2008, but the yield has not increased significantly. The industry is relatively labor-intensive, with mechanization taking place slowly. Total production was around 65 million tons (mt) in 2007; however, the yield of sugarcane is susceptible to climate change and disease. In addition, the cost of production has increased steadily over time, from B22,888/ha ($568.36) in 2004 to B36,450/ha ($1,054.69) in 2007, notwithstanding the government's desire to bring down the cost by improving the yield of sugarcane, while holding the planted area constant.

Consequently, cassava became more attractive as an ethanol feedstock. Cassava was a natural alternative to sugarcane because of its ample supply and low prices. Furthermore, it is easy to grow, even in poor soils. Many of the ethanol plants now under construction will draw their feedstock from cassava.

Cassava was ignored at the outset because the early development of the ethanol industry was largely propelled by sugar millers, and cassava had been in great demand abroad. Its potential uses are very wide, ranging from simple animal feed, in the form of pellets and chips, to starch and degradable plastics. In 2007–2008, when the world began to experience a dramatic rise in food prices, maize and soybeans became more expensive and farmers sought alternative feed, such as cassava, for raising animals. In addition, the spectacular economic growth of the People's Republic of China (PRC) demanded feedstock for expanding industries, which were met through imports. The price of cassava increased in early 2008 in response to these demands. However, after the 2008–2009 harvest, it started to tumble, because of the economic recession across the world, and the expansion of cassava production.

The challenge for the government was to increase the cassava yield on the same acreage because an expansion of the area planted to cassava could jeopardize the production of other crops. But in the absence of enforcement measures, such control is not possible, and at times of high cassava prices, profit-maximizing farmers can be expected to expand their planting areas. In addition, economic efficiency will determine the allocation of scarce resources, and it is natural for sugarcane farmers to turn to cassava and maize instead. The total production of cassava can therefore be expected to increase through acreage expansion and the greater use of inputs. This trend will be more pronounced when the price is attractive enough to induce early-season harvesting. The cassava industry will be faced with the choice of continuing to supply its traditional overseas markets or orienting production to the new domestic market propelled by ethanol production.

Under the policy of the government, consumers are encouraged to use gasohol 95 and gasohol 91. Gasohol E20 was introduced in 2007, and benzene 91 will be phased out in 2011. This means that ethanol requirements will rise from 1.27 million l/day to 2.40 million l/day—almost doubling in 4 years (Table 2). In estimating the amounts of molasses and cassava for ethanol production, it is assumed that the ratio of molasses to cassava will change from 80:20 in 2008 to 50:50 in 2011. Therefore the amount of molasses required in the next 4 years under the government biofuels mandate is less than that which will be available after the domestic uses and exports are taken into account (Table 4). For example, in 2008 the amount of excess molasses is 1.87 mt, but the requirement for bioethanol under the government biofuels mandate is estimated at 1.48 mt. Thus, there is a net surplus of 0.39 mt. With cassava, the situation is similar to that of molasses (Table 5). The net surplus is 0.38 mt in 2008, increasing to 5.65 mt in 2011.

Table 4: Molasses Required for Ethanol Production
(million tons)

Item	2008	2009	2010	2011
Excess molasses over domestic uses and exports	1.87	1.88	1.90	2.18
Molasses required to produce ethanol	1.48	1.62	1.69	1.75
Net surplus	**0. 39**	**0.26**	**0.21**	**0.43**

Note: Excess molasses takes into account stock carryovers.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

Table 5: Cassava Required for Ethanol Production
(million tons)

Item	2008	2009	2010	2011
Excess cassava over domestic uses and export	0.92	3.00	5.93	8.22
Cassava required to produce ethanol	0.54	1.02	1.66	2.57
Net surplus	**0.38**	**1.98**	**4.27**	**5.65**

Note: Excess cassava takes into account stock carryovers.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

Table 6: Crude Palm Oil Required for Biodiesel Production
(million tons)

Item	2008	2009	2010	2011	2012
Excess CPO over domestic consumption and export	0.50	0.62	0.79	1.28	1.38
CPO required to produce B100	0.39	0.45	0.47	1.02	1.06
Net surplus	**0.11**	**0.17**	**0.32**	**0.24**	**0.32**

B100 = pure biodiesel, CPO = crude palm oil.

Note: CPO production = production of existing plantations and production of new plantations under 5-Year Plan. Excess CPO takes into account stock carryovers.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

It is safe to say that under the government biofuels mandate, and taking into consideration government projections based on the assumption of the composition of raw materials, the supply of feedstock is sufficient at least until the end of 2011.

Crops for Biodiesel Production

Oil palm is the single most important crop for the production of biodiesel in Thailand. Other crops such as coconut and jatropha are not attractive enough to compete with oil palm. Coconut plantations have dwindled in the last two decades and much of the land has been diverted to other uses such as tourism. The returns to domestic coconut production are minimal, and Thailand is now dependent on copra imports.

Despite many claims that jatropha is a miracle crop that can grow under almost any conditions, it has yet to produce the momentum it needs to become an important feedstock for Thailand's biofuel industry. So far, government efforts in relation to jatropha have been involved in promoting the planting of the crop by providing free seedlings at first, and disseminating knowledge on how the seeds could be pressed into crude oil and how farm engines would make use of it. Pilot community-scale dehulling and extraction equipment was demonstrated to farmers and to farmers' groups. But the acreage under jatropha has not expanded to any significant extent. In fact, it had not gone beyond the commercial sale of seedlings, which was promoted in 2004. There was no market for commercial feedstock, and consequently the jatropha growers reverted to other crops. Nonetheless, there are a few private companies involved in the production of biodiesel from jatropha. Thus the price of the seeds is high, but plantings are limited to small pockets. The development of jatropha will suffer if farmers cannot find markets for their harvest. There is no plant in the country for large-scale extraction of oil from jatropha, and less efficient community-level pressing equipment is only available for demonstration purposes.

To assess the availability of feedstock for biodiesel production, the amount of excess crude palm oil (CPO) over domestic consumption and export for 2008–2012 is estimated (Table 6). The amount of CPO required to produce B100 in response to the government policy on biodiesel is projected over the same period. The net surplus every year indicates that there is no danger that the feedstock will be in short supply, so under government projections, food security will not be threatened.

The situation described for biofuel crops does not imply that there is room for complacency regarding feedstock availability for biofuel production. Underlying the projections is the assumption that the rest of the economy will continue to develop at its current pace and in the same direction. However, this is not likely. The factors that influence feedstock production, consumption, and trade are strongly interrelated. Thailand is heavily dependent on exports and the demand for the country's cassava exports can be volatile in cases where competition is strong and substitute products are available for cassava chips, starch or pellets. The demand for bioenergy crops and their products as food depends on a range of factors and cannot simply be treated as a given. The projection scenario described above must be interpreted carefully and taken with caution.

Detailed Assessment of Sugarcane

Between 2004 and 2007, over 200,000 farm households grew sugarcane in Thailand. The planted area is around 1 million ha, and production is 60 mt/year (Table 7).

About a third of the sugar produced was consumed domestically; the rest was exported. The price of sugarcane was B683 per ton (/t) ($19.76) in 2007. The National Sugar Cane and Sugar Board operates under the law on sugarcane and sugar. It supervises and regulates production and marketing through the Sugar Cane Committee and the Sugar Committee. The board monitors the development of biofuels closely, but has not interfered so far, since it is the by-product, rather than sugar, that forms the main feedstock for ethanol production. When sugarcane is used directly as feedstock, the board may decide to intervene to prevent any adverse effect on sugar production and on the returns to the sugar industry. Already, some sugar millers—most notably the Mitr Phol Sugar Group—have expanded their operations by converting molasses into ethanol.

Detailed Assessment of Cassava

Cassava cultivation in Thailand covers an area of about 1 million ha. The total production was about 26.92 mt in 2007 (Table 8), and the yield was 22.93 t/ha in 2007, rising from 20.28 t/ha in 2004. The cost of production has increased steadily, because of the rising cost of tractors for plowing and labor for harvesting. Cassava farm prices at the beginning of 2008 were high at B2,400/t ($75.97). More cassava will be grown in the coming years, probably at the

Table 7: Basic Fact Sheet for Sugarcane

Item	Unit	2004	2005	2006	2007
Farm households	number	223,213	223,213	223,213	223,213
Planted area	million ha	1.12	1.07	0.97	1.01
Production	million tons	65.00	49.60	47.70	64.40
Yield	tons/ha	57.90	46.40	49.40	63.70
Cost/ha	$	568.36	600.17	743.47	1,054.69
Sugar production	million tons	6.99	5.17	4.84	6.72
Domestic consumption	million tons	2.18	2.48	2.28	2.07
Exports of sugar	million tons	4.60	3.04	2.24	4.42
Farm price (at farm gate)	$/ton	9.14	12.91	17.61	19.76

ha = hectare.

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Table 8: Basic Fact Sheet for Cassava

Item	Unit	2004	2005	2006	2007
Farm households	number	507,770	464,956	476,352	474,823
Harvested area	million ha	1.06	0.99	1.07	1.17
Production	million tons	21.44	16.94	22.58	26.92
Yield	tons/ha	20.28	17.18	21.09	22.93
Cost/ha	$	367.37	401.04	468.97	546.70
Domestic consumption	million tons[a]	3.40	3.65	4.26	7.82
Exports [b]	million tons	6.65	4.66	6.56	6.54
Farm price	$/ton	23.59	34.02	31.90	52.66
Ethanol production [c]	million tons	—[d]	—[d]	0.21	0.26

ha = hectare.

[a] Weight in fresh roots.

[b] In various product forms. Conversion rates are:

1 kg of dried cassava chips	= 2.35 kg of fresh roots
1 kg of dried cassava pellets	= 2.45 kg of fresh roots
1 kg of starch	= 4.66 kg of fresh roots

[c] Included in domestic consumption. Conversion rate is 1 liter of ethanol = 6 kg of fresh roots.

[d] No ethanol plant operational.

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

expense of sugarcane and second-season rice. This effect is location specific and total rice production may not be significantly affected, because cassava does not grow well in lowland areas. It also cannot survive well in waterlogged areas and does not give a good yield in clay-rich soils. Also, second-season rice comprises only a fifth of the total annual rice harvest.

The main reasons for high cassava prices can be traced to the recent demand for cassava and cassava products within the country and overseas, particularly from the PRC. Rising prices of feed crops and cereals in the rest of the world made cassava exceptionally attractive. It has not traditionally been the main ingredient in the animal feed industry, but over the past decade it has been shown repeatedly that its nutritional value is at least as good as other animal feed ingredients. It is also cheap compared with maize and soybean meal. The livestock industry, particularly swine and dairy farms, consumes huge quantities of cassava.

Cassava is now being used as feedstock in some ethanol plants. Its high prices in 2008 posed a serious problem to the biofuel industry. However, prices dropped in early 2009, because of the world economic recession and strong competition from other exporting nations. This occurred in spite of the government's price support scheme.

Detailed Assessment of Oil Palm

Thailand produces 6.6 mt of oil palm fruits each year, and production will increase steadily as more oil palm plantations reach maturity. Oil palm is traditionally grown in the south and has gradually spread to the eastern region of the country. It was introduced in the northeast recently, following the expansion of rubber plantations there. Palm oil is both imported and exported any given year (Table 9). This occurs because at harvest time the surplus is too large to be absorbed by the domestic industry, and it is therefore exported; while at other times in the year, palm oil is short in supply, so it is necessary to import CPO to meet the domestic demand for cooking oil.

Table 9: Basic Fact Sheet for Oil Palm

Item	Unit	2005	2006	2007
Farm households	number	81,472	85,546	87,277
Planted area	million ha	0.44	0.47	0.51
Harvested area	million ha	0.32	0.38	0.43
Production	million tons	5.00	6.72	6.61
Yield	tons/ha	15.43	17.68	15.52
Cost/ha	$	642.39	712.94	822.05
Domestic consumption	tons	821,406	953,094	977,400[a]
Import	tons	48,953	34,871	38,688
Export	tons	195,673	304,810	413,617
Stock at end of year	tons	113,669	164,521	106,758
Farm price	$/ton	68.54	63.01	117.77

ha = hectare.

[a] Includes 100,000 tons for biodiesel production.

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Overall, Thailand is a net exporter of palm oil. The situation is now changing rapidly with the entry of large biodiesel plants that require a steady supply of CPO as their feedstock. Exports of CPO may cease in the near future. Instead there may be an increase in imports to accommodate the rapid growth in biodiesel production and plug the shortfall in supply when local palm oil is insufficient to meet the additional domestic demand for biodiesel production, and while alternative energy sources such as jatropha are still not commercially available.

Production Potential

Crops with potential for biofuel production were analyzed using satellite digital images from 2005–2006 taken by the Landsat 5 Thematic Mapper. Experts of the Department of Land Development interpreted the images. A crop simulation model developed by the Department of Agriculture was employed to evaluate crop production based on the soil potential, climate, and field management systems. Satellite digital images have drawbacks, but they are nevertheless the best way to obtain in-depth, factual information on crop production, which can be used to evaluate the production potential of bioenergy crops.

The results differ from the sample surveys undertaken. The shortcomings do not stem from the crop simulation model, but from the deficiency of the Landsat images in providing satellite image interpretation over the entire cropping season. Satellite image interpretation provides only a partial picture and estimation at any given point in time. Utilizing such interpretation could lead to errors. Satellite images can be blocked by natural phenomena such as clouds, and complete information on crop production may not be obtained. A wide-ranging set of variations can also affect the plantings over the harvest season. Aside from weather conditions, diseases and pests that affect crops are not captured by the satellite images. A cost factor may also be involved in the acquisition of continuous, up-to-date satellite images over a period of time. The process is rather expensive and the resulting interpretation work is prohibitive and time-consuming. With these provisos in mind, the results for four important biofuel crops are presented.

Sugarcane

Landsat images show that the planted area of sugarcane was 0.80 million ha in 2005 and had increased to 0.83 million ha in 2006. The yield did not vary much over this period. Applying the crop simulation model to the data obtained from the images showed that the yield was about 70 t/ha (Table 10). The planted area is subdivided into regions and provinces, and data for this level of detail can be found in the Appendix.

A comparison of the data in Tables 7 and 10 reveals discrepancies in the planted area, yield, and total production. For example, for 2005, production was 49.6 mt in Table 7, but 55.8 mt in Table 10. The data in Table 7 were obtained or deduced from individual production records in sugarcane production zones. Those records were not regularly updated, but could provide a strong indication. These points must be kept in mind when interpreting the data. One encouraging observation from the satellite images is that the yield of sugarcane is much higher than the production records indicate. This shows that the potential for further increasing production through yield improvement indeed exists.

Cassava

The area planted to cassava was found to be 1.0 million ha and the yield was 24.9 t/ha during the 2006 crop year. Table 11 shows the planted area and total production by region. The data by region and province are given in the Appendix. Again, there are

Table 10: Sugarcane Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Whole Kingdom

Region	2005		2006		Increase or decrease	
	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
North	173,797	14.24	182,912	14.91	9,115	0.67
Central	281,466	19.70	286,295	20.10	4,830	0.40
East	52,874	3.34	57,392	3.63	4,517	0.30
Northeast	292,586	18.54	302,228	19.19	9,643	0.65
Total	**800,723**	**55.82**	**828,827**	**57.83**	**28,105**	**2.01**

t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table 11: Cassava Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Whole Kingdom

Region	2005		2006		Increase or decrease	
	Area	Production	Area	Production	Area	Production
Central	50,611	1.22	55,878	1.35	5,267	0.13
East	253,485	7.16	257,976	7.30	4,491	0.13
North	159,881	3.54	166,445	3.68	6,564	0.14
Northeast	582,187	14.12	606,554	14.77	24,367	0.66
Total	**1,046,164**	**26.04**	**1,086,853**	**27.10**	**40,690**	**1.06**

t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

discrepancies between the data in Tables 8 and 11. It can be seen that the planted areas are nearly the same, but the total production diverges significantly. As was the case with sugarcane, the yield in the crop simulation model using the satellite images is higher than that in Table 8, which was obtained from the sample survey and rural interviews conducted in the field.

In the Cassava Strategic Development Plan, the government contends that cassava production must be increased on the existing cultivated area. Expanding the land area is regarded is infeasible, since incursion into the remaining forests will not be tolerated, and the production cost for cassava can no longer be lowered by increasing the acreage. Instead, more suitable or improved varieties need to be introduced to match varieties with soil types and more efficient farm management practices need to be promoted. There has already been considerable progress in this area.

Cassava farmers now use fertilizers regularly, unlike in the past when land was newly opened for production and soil fertility was high. As cassava yields dwindled because of continued nutrient depletion, farmers resorted to applying chemical fertilizers in their cassava fields. Chemical fertilizers have become increasingly expensive, and farmers are therefore forced to use organic fertilizers and animal manure instead.

In an attempt to reap the benefits from high cassava prices, farmers harvest cassava roots early and sell them to the drying silos. Some of the roots are still young, as they are harvested at 6 months instead of the optimal 11 months. As a result, the yield and starch content are low. Nonetheless, the farmers still prefer to harvest early. This practice has also led to another unintended outcome. The usual practice in the past was to leave around 10% of cassava unharvested so that the stems can be used for replanting. However, when prices are high, all cassava plants are harvested for sale and the early harvest results in cassava cuttings that are immature for replanting and would give low yields. The government is aware of this problem, but cannot force the farmers to delay harvesting, since there is a high degree of uncertainty about the future prices of cassava. At best, it can acquaint cassava farmers with the advantages and disadvantages of early harvesting.

In the future, another option for the government is to introduce short-duration varieties with a considerable yield and starch content. The Thailand Tapioca Development Institute, under the royal patronage of Her Royal Highness Princess Maha Chakri Sirindhorn, will help smooth the transition for farmers who seek to adopt the early harvest practice in their cassava operations by working closely with Kasetsart University and the Department of Agriculture to develop short-duration varieties.

Oil Palm

A total of 322,028 ha of the country are planted to oil palm (Table 12). About 126,000 ha, or around 40% of the area, have a low yield potential of less than 12.5 t/ha. A quarter of the land with higher yield potential can produce more than 25 t/ha. The provincial breakdown is given in the Appendix.
A major challenge for the government and other stakeholders is to find a way to improve the yield performance, especially in the low-yielding areas.

Table 12: Oil Palm Planted Area, Interpreted from Landsat Image 2005–2006, and Production Estimated from the Crop Model: Whole Kingdom

	Planted area (ha) with yields (tons/ha/year) of:			
Region	**<12.5**	**12.5–25.0**	**>25.0**	**Total**
South	124,981	113,087	82,072	320,139
East	1,020	869	—	1,889
Overall total	**126,000**	**113,956**	**82,072**	**322,028**

— = accurate data unavailable, < = less than, > = more than, ha = hectare.

Source: Department of Agriculture.

Countrywide, 5 million ha were found to have potential for oil palm cultivation. However, the area actually planted to the crop accounts for only around 7% of this potential; so there is much scope for expanding the area under oil palm. The traditional stronghold of oil palm is in the south, but there are indications that the crop is fast expanding to the east and northeast, along the Mekong River. The south of the country is known for its fruit orchards and commercial plantations of rubber and oil palm. In the northeast, rubber growing started slowly in the 1990s, but within a decade it had gained a strong foothold. Oil palm expansion is a recent phenomenon, partly supported by southern plantation owners and northeastern farmers, who seek new investment options and who have accumulated farming experience working in the south.

In common with many farmers, Mr. Somdech from Bung Khan District, Nong Khai Province on the banks of the Mekong River, bought 450 oil palm saplings to grow on his farm. He is a rubber tapper in the south, but prefers to grow oil palm in his hometown. Such transfer of knowledge by migrant workers is common in Thailand and contributes to the growth of agriculture.

Jatropha

Jatropha can grow in poor soils. It is poisonous and is commonly grown as hedge or fence to exclude cattle. It is easily propagated through seeds or cuttings and has a life span of up to 50 years. Latex from its seeds is used in traditional medicine, and its bark can be made into paper. The oil obtained by crushing the seeds can be used for lighting and to run engines. The seedcake, a by-product from pressing the seeds, can be used as organic fertilizer or burned to generate electricity.

The development of jatropha in Thailand began with a major campaign in 2004. At the start, the government provided seedlings to the farmers and demonstrated how oil could be extracted from seeds with the use of village-scale pressing equipment, and showed how the crude oil could be used to run a farm tractor. The campaign quickly transformed itself into a commercial venture that produced seedlings for sale for a quick profit. There is no large-scale market for jatropha seeds for conversion into biodiesel so far, and all commercial plants are still at the planning stage. Many farmers have continued producing seeds to sell to nurseries that resell them as seedlings to others who are interested in growing the crop. Some growers later found that it was difficult to sell the seeds. They then destroyed the plants and converted the land for other more profitable crops. Despite the many uses of jatropha, it appears that major efforts will be required to attract more growers.

One of the obstacles facing jatropha is that although it can easily be converted into crude oil to run small farm engines, it must be further refined into biodiesel and blended with conventional diesel if it is to be used in ordinary motor vehicles. Another problem is that seed collection is not easy, as the plant grows mostly on small tracts of land. It has not been grown in larger areas to justify economies of scale for commercial oil extraction plants and refineries. It is also true that jatropha does not generally produce high yields without proper farm management and adequate farm inputs. The fruits do not ripen at the same time and thus have to be handpicked for greater oil recovery rates. These drawbacks have discouraged many farmers from growing the crop.

In its favor, jatropha remains attractive to small and marginal farmers who maintain cash crops as their main source of income, and to those with small patches of idle land. Family labor can be employed, particularly to harvest and dehull the seeds, thereby saving the cost of hired labor. The tree can bear fruit within 6 months of planting, and can be a source of carbon credits. It does not need constant care, and can grow under even harsh, dry conditions. It is a crop well suited to the Sufficiency Economy Principle.[5]

Much of the interest now remains with the private sector. The jatropha nursery business will not be sustainable unless jatropha is grown on a larger scale. However, in the international arena the crop is still regarded as having potential for the biodiesel industry, particularly when the price of fossil fuel is high and reducing greenhouse gas emissions is an objective. Foreign investors are making considerable efforts to revive the planting of jatropha on a commercial scale.

[5] The Sufficiency Economy Principle was introduced by His Majesty the King of Thailand. It is an approach to life and has three components: moderation, wisdom, and resilience against risks that arise from internal and external change.

A few small private companies produce biodiesel from jatropha for limited local consumption and for export. Large oil extraction plants are planned and will begin operations in the next few years. The future demand for feedstock will be high and hundreds of thousands of hectares will be needed to meet this demand. This offers the chance for cross-border trade with neighbors in the Greater Mekong Subregion (GMS) that can grow and export jatropha. In order for jatropha to become a viable source of feedstock for the biofuel industry, a range of problems will need to be overcome, such as the poor cultivation techniques used by small farmers, the small size and scattered location of their land, the prohibitive cost of transport to the processing plants, low inputs and low yield, and the need to ensure the availability of labor at harvest time. Research and development efforts can help overcome these problems. In addition to better farm management practices, improved varieties need to be developed that give high and stable yields, and produce fruits that ripen at the same time to facilitate mechanical harvesting. These advances would position jatropha as a viable alternative to the edible food crop, oil palm.

Summary of Production Potential

From the preceding analyses, the production potential of the main biofuel crops may be summarized as follows:

Sugarcane

The crop simulation model gives a higher total production potential than that which was achieved. Greater efforts should be exerted to improve farming practices so as to obtain higher yields through the use of improved varieties—such as drought-resistant strains—and improved access to irrigation. These improvements could produce yields comparable with other sugarcane-producing countries (Table 13).

Thailand is the fourth largest sugarcane producer in the world, but the yield achieved by Thai farmers is lower than that of most of their counterparts elsewhere. The 30% increase in sugar prices allowed by the government could cause sugarcane prices to rise, and this in turn would give added impetus for sugarcane farmers to improve their yield and expand their crop acreage.

Table 13: Yield of Sugarcane, by Country, 2004–2007

	Yield (tons per hectare)			
Country [a]	**2004**	**2005**	**2006**	**2007**
Brazil	73.9	72.9	74.4	76.6
India	59.3	64.8	66.9	—
PRC	65.4	64.1	82.6	86.9
Thailand	57.9	46.5	49..4	63.7
Pakistan	49.7	46.2	49.2	53.2
Mexico	75.6	77.1	74.5	74.5
Colombia	91.5	93.6	92.9	88.9
Australia	82.6	87.2	92.0	85.7
Philippines	65.8	84.5	62.1	63.3
US	69.3	64.7	73.5	75.7
Others	58.6	59.4	58.7	59.2
World	**65.0**	**65.8**	**67.9**	**70.4**[b]

— = accurate data unavailable, PRC = the People's Republic of China, US = the United States.

[a] Countries are ranked in terms of harvested acreage.

[b] This figure excludes India. The Indian yield as published is erroneous and hence is omitted.

Source: Food and Agriculture Organization of the United Nations and the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Cassava

Cassava farmers can increase their yield through the use of improved varieties, irrigation investments, and soil improvement. The Ministry of Agriculture and Cooperatives (MOAC) has developed improved varieties. Kasetsart University has introduced its own variety, KU 50, which has proved popular with farmers. The Thailand Tapioca Development Institute has promoted the use of the Huay Bong 60 variety for about 10 years, and is now introducing Huay Bong 80 to farmers. In the eastern part of Nakhon Rachasima, farmers' investment in irrigation facilities for cassava fields is paying off. Also, breaking the hardpan in the subsoil allows cassava to secure more nutrients from the soil and to better withstand drought. The use of vetiver grass, along with green manure and compost, reduces soil erosion and raises soil fertility.

Demonstrating these practices to farmers has contributed to higher output. The unprecedented rise in the farm price of cassava in 2008 has also induced farmers to expand production and apply extra inputs to the land to increase yields.

Oil Palm

Many old plantations need to replace their plants with new, improved varieties for increased yield. In addition, the government must certify the oil palm saplings to assure farmers that the plants are genuine. In new areas, such as the land in the northeast bordering the Mekong River, the government has devised a scheme in which saplings are provided to the farmers on the condition that they pay back the cost when the first harvest is ready. The farmers can also pay for the saplings right away, if they so wish. The price is competitive, compared with that in private nurseries. The planted area is so far only 7% of the total suitable land for oil palm, and huge potential exists for expansion in the northeast.

Jatropha

The basic strategy for jatropha production is to encourage small farmers to grow it on small tracts of land so that primary cash crops are not affected. The planned construction of biodiesel plants for jatropha seeds will assure the farmers of a market for the seeds they produce.

Strategic Development Plans for Biofuel Crops

Strategic development plans for biofuel crops take into account the government policy and programs in biofuels that originated on 2 September 2003, when the cabinet agreed to raise the level of renewable energy consumption from 0.5% of total energy consumption in 2002 to 8.0%, or 6,540 thousand tons of oil equivalent, by 2011. As prescribed by the cabinet resolution, biofuels would constitute 24% of all renewable energy produced and would be channeled primarily for use in transport. The strategic development plans for important bioenergy commodities—sugarcane, cassava, and oil palm—have been revised several times, largely because of the rapidly changing economic environment that affects their markets. Jatropha is regarded as a minor biofuel crop, and hence there is no strategic development plan for it. The production targets contained in the latest version of the development strategies is summarized in Table 14.

The overriding concern at the time when the development plans for sugarcane and cassava were formulated was the low prices received by farmers and the need to reduce the costs of production by increasing crop yield. The area planted to sugarcane will remain at 0.96 million ha until 2012, and the rising demand will be met through yield increases. By 2012, total production is expected to reach 71.6 mt, equivalent to 7.4 mt of sugar.

The land planted with cassava will be held constant at 1.18 million ha, producing 34.8 mt of the roots by 2012. According to the strategic development plan for cassava, 60% of the total production will be exported in various forms and the remainder will be channeled to domestic consumption and ethanol production.

For oil palm, the underlying concept is to increase production to meet the ever-increasing need for cooking oil and the rising demand for biodiesel. Therefore, the land planted to oil palm must expand in the next 5 years. The planted area of oil palm will increase from 0.55 million ha in 2008 to 0.87 million ha in 2012 (Table 14). The yield is to increase from 17.4 t/ha in 2008 to 20.1 t/ha in 2012. In the development plan for the oil palm industry, total production will jump from 8.4 mt to 13.6 mt between 2008 and 2012.

Prioritization of Biofuel Crops

Criteria for Prioritization

The selection of sugarcane, cassava, oil palm, and jatropha as feedstocks for processing into biofuels is based primarily on their production potential. This in turn is dictated primarily by the interaction of various physical parameters, including soil characteristics, climate, water and other natural resources, the farming system, and farm management. Other criteria for prioritization—which deals with the economic, social and environmental conditions of the stakeholders—include the competing uses of the biofuel crops, the extent they pose threat to

Table 14: Production Targets of the Strategic Development Plans for Specific Commodities

Commodity	2008	2009	2010	2011	2012
Sugarcane					
Acreage (million ha)	1.02	0.96	0.96	0.96	0.96
Yield (tons/ha)	68.1	70.6	71.9	73.1	74.4
Total production (million tons)	**69.8**	**67.9**	**69.1**	**70.0**	**71.6**
Cassava					
Acreage (million ha)	1.19	1.18	1.18	1.18	1.18
Yield (tons/ha)	23.1	25.0	26.6	28.1	29.3
Total production (million tons)	**27.4**	**29.6**	**31.5**	**33.3**	**34.8**
Oil palm					
Planted acreage (million ha)	0.55	0.63	0.71	0.79	0.87
Harvested acreage (million ha)	0.48	0.52	0.55	0.61	0.68
Yield (tons/ha)	17.4	17.8	18.6	19.7	20.1
Total production (million tons)	**8.4**	**9.2**	**10.2**	**12.1**	**13.6**

ha = hectare.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy; and the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Table 15: Bases for Prioritizing Biofuel Crops

	Uses as Food, Feed, and Fuel	Threat to Food Security	Economic Risks Facing Primary Producers	Impact on Environment Based on Existing Farming Practices	Impact on Land Use and Potential for Conflicts	Favorable Impact on Climate Change	Marginalization of Small Farms
Sugarcane	Competing	Little	Yes	No	No	No	No
Cassava	Competing	Little	No	Yes	No	No	No
Oil palm	Competing	Considerable	Yes	Yes	Yes	Yes	Possible
Jatropha	Complementary	Little	Yes	No	No	Yes	No

Source: Authors.

food security, the economic risks to biofuel primary producers, their effect on the environment based on existing farming practices, their impact on land use and land use issues, their effect on climate change mitigation, and whether they marginalize small farmers (Table 15).

Uses as Food, Feed, and Fuel

Of the four crops, only jatropha is not consumed as food; neither is it directly used for animal feed, although experiments are being undertaken on the use of jatropha seedcake for feed. It does not compete with food crops for the use of land resources, primarily because it is grown in small parcels of land that are usually have no other productive use. However, it could complement food production in the sense that land devoted to food production remains unaffected and the seedcake as by-product from crushing the seeds can be used as organic fertilizer for the food crops.

Threat to Food Security

Sugar and cassava products have traditionally been exported. The supplies are ample, but during difficult times, exports can be restricted to ensure availability to domestic consumers. The amount of palm oil demanded by biodiesel producers is rising and can have repercussions on the domestic demand for palm oil for cooking and as a food ingredient. In the next few years, exports could be reduced to zero when the surplus supply is absorbed by local biodiesel processing plants.

The emerging situation is more serious than was initially thought, however. Before it became important for biodiesel production, the oil palm supply had exhibited a cyclical pattern of incurring surpluses for possible export after the harvest season, followed by the need for small imports to satisfy the demand from cooking oil processing plants prior to the next harvest. With the introduction of biodiesel in 2007, this cyclical pattern has undergone a fundamental change, with sustained and increased domestic demand for biofuel feedstock and reduced exports. A shortage of cooking oil, whether superficial or real, was experienced in early 2008.

Cooking oil is one of the basic commodities controlled by the government to ensure that it is available and affordable for consumers. The government's announcement of price increases ahead of schedule prompted consumers, restaurant operators, food processors, and street vendors to hoard substantial amounts. Cooking oil disappeared from supermarket shelves within a short time, and had to be rationed. However, it could be purchased at a higher price in wet markets, where government supervision was rather lax. The dramatic rise in the price of cooking oil, especially palm oil, toward the end of 2007 and in early 2008 exemplifies the conflict between food and feedstock, and the potential threat to food security when food crops are used as biofuel feedstocks.

Economic Risks Facing Primary Producers

Economic risks are those associated with price movements. Cassava prices in the post-2008 era will be lower, but are likely to remain slightly higher than the level prior to the increase. In contrast, sugarcane prices will be affected by the price of sugar on the international market, which tends to be low and fluctuating compared with the domestic price. The supply of palm oil is greatly influenced by producers in Malaysia and Indonesia. Even though the government regulates palm oil in terms of its price and availability, the demand can be dampened by unwarranted imports. Land planted with jatropha is limited, and there is no industrial demand for the seeds, except occasionally for seedling cultivation. However, there is high demand for cassava as a food ingredient in the form of starch, as animal feed, and as a feedstock for ethanol production. The increase in demand may also have been brought about by the massive use of maize as a feedstock for ethanol by the United States, which is the largest producing country, and this in turn has put upward pressure on the demand for cassava as a valuable alternative in the animal feed industry. In addition, the government has operated the cassava pledging scheme[6] for many years until the present. Thus, among the four main bioenergy crops, cassava is likely to have lower economic risks.

Impact on the Environment Based on Existing Farming Practices

The cultivation of jatropha and sugarcane is less damaging to the environment than oil palm and cassava. Sugarcane production takes place around sugar mills, whose location and capacity are controlled by the government. The use of chemical fertilizers is widespread, but insecticides are limited. Biological control of plant pests is usually practiced, as it is quite effective. Herbicides are sprayed only when sugarcane is young, as when vegetative growth is active herbicides are no longer required.

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5 The cassava pledging scheme is also sometimes known as the commodity loan scheme. Under the scheme, advance payment is made to the farmer for the harvest at a pre-determined price, and by the end of a time period the farmer can decide whether to repay and sell the harvest at the going price or to accept the original payment as the final sale.

Cassava consumes a lot of nutrients and a large number of farmers have sought to apply chemical fertilizers. Recently, cassava growers have begun to use chicken and cow manure on their farms to improve productivity. However, improvement has not occured on a wide scale. Much cassava and oil palm is grown in degraded forestland. This practice has a direct effect on the environment because the crops help accelerate the destruction of the remaining natural habitat. As investments to maintain or restore soil fertility and stop soil erosion are costly, growers usually ignore soil and water conservation measures. Jatropha is grown in small tracts of land and will have little or no impact on the environment.

Impact on Land Use and Potential for Conflicts

Sugarcane is grown on fertile soils, preferably with irrigation. It has replaced cassava in many places, but its expansion is limited by the location of the sugar mills. The impact of sugarcane producers on land use is limited, as the government tightly controls the number and capacity of sugar mills. However, oil palm is likely to pose a problem when the government starts to encourage farmers to grow it. Oil palm is a perennial crop, and expansion of its area can and does occur in degraded forest reserves. The plantations tend to be large and require considerable investment; therefore, their impact on land use tends to be more permanent. The production cost of cassava is relatively low, so farmers have started to use chemical and organic fertilizers. But most producers are poor and hence the application of these inputs is limited and this probably accounts for the continued decline in productivity. Land use for cassava production is likely to persist over time. In the case of jatropha, the growers are likely to be small farmers using idle, marginal land, and so the cultivation of jatropha is expected to have a favorable impact on land use.

Most potential biofuel crops do not seem to present serious problems with respect to land use. Sugarcane and cassava production are well established in Thai farming communities. The introduction of jatropha has been much more recent. It does not require large tracts of land because the fruit has to be harvested by hand; therefore land use issues in this case are likely to be minimal. In contrast, oil palm plantations can cover a sizeable area and involve large investments compared with other crops. Expansion is easy, as plantation owners are better off, and some are directly involved in the oil palm processing business. Thus, they may face land-use conflicts. If the land is designated as forest reserves—as is often the case—it cannot easily be reforested without legal entanglement from the oil palm growers, since the investment in the land is high and the return from the perennial crop stretches over 20 years. Over time, the undesirable situation may arise in which vast tracts of land are converted to a monocrop of oil palm.

Favorable Impact on Climate Change

Since both oil palm and jatropha are perennial trees which can be cultivated for 20 years or longer, they sequester more carbon than annual crops such as sugarcane and cassava, so they have a favorable impact on climate change. Because jatropha needs to be pruned for better yield and easy handpicking of the fruit, it is likely to be less efficient at sequestering carbon than oil palm. However, this can be made up for by intercropping between rows and plowing the prunings back into the soil.

Marginalization of Small Farmers

Cassava farms are usually small, and the holdings in which jatropha is grown also tend to be small. Very few sugarcane farms are large, accounting for several thousand hectares. Large farms and plantations are more common with oil palm. This can take place through consolidating small and adjacent tracts of land into larger holdings. In so doing, small farms are effectively marginalized.

Economic Comparison of Certain Crops

A comparison of the economic returns from cassava and sugarcane shows that in the average crop years of 2005 and 2006 the net profit from cassava was B4,363/ha ($138), while the profit from sugarcane was estimated to be B5,225/ha ($165) (Table 16). However, the price of cassava received by the farmers was only two-thirds of the price set by the government under the commodity pledging scheme. If only the government price is considered, growing cassava would have brought much higher returns than sugarcane. In fact, the price of cassava in 2008 was at a record high but this barely benefited the farmers. The average price of cassava is much more volatile than that of sugarcane because a large proportion of production is exported.

Table 16: Economic Comparison of Cassava and Sugarcane, Crop Year 2005–2006

Item	Cassava	Sugarcane
Yield (tons/ha)	21.6	60.1
Farm price (B/ton)	1,050	600
Total income (B/ha)	22,706	36,275
Total cost (B/ha)	18,344	31,050
Net profit (B/ha)	4,363	5,225

B = baht, ha = hectare.

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Table 17: Economic Analysis of Oil Palm and Rubber

	Oil Palm		Rubber (RSS3)	
At NPV (B/ha)	Price (B/kg)	IRR (%)	Price (B/kg)	IRR (%)
204,044	2.50	25.7	46.26	20.2
278,606	3.00	31.2	58.59	23.5
347,613	3.46	35.7	70.00	26.1

B = baht, ha = hectare, IRR=internal rate of return, kg = kilogram, NPV = net present value.

Note: RSS3 = Third-grade rubber smoke sheet.

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Sugarcane prices, on the other hand, remained stagnant during 2005–2008. A drop in sugarcane prices will not affect the sugar industry much in the short run, but may have an adverse impact in the long run, when farmers attain greater flexibility in their investment decisions. Sugarcane can be harvested three times before replanting. The cost of production is therefore higher in the first year than in subsequent years. At the end of the third year, farmers may seek to invest in other more profitable crops instead. However, sugar millers are determined to keep the industry afloat at all times. This can be done through the provision of farm credit and the system of networking with the farmers via sugarcane quota leaders. Under these circumstances, sugarcane production is likely to persist and molasses will be sufficiently available for ethanol production for quite some time.

Because of the high cassava prices in 2008 and the relatively greater tendency for the price of this crop to fluctuate, the ethanol industry is reevaluating the use of cassava as a feedstock. The Siam Ethanol Company has complained that it would not be able to operate if cassava prices rise to B2.00/kg ($0.06) and higher. Overall, sugarcane appears to be a better choice of feedstock than oil palm and rubber.

Oil palm and rubber can compete for land, particularly in the south where they are mostly grown. When compared against rubber (third-grade rubber smoked sheet) at the same level of net present value, oil palm becomes more attractive, with a price of around B4.00/kg ($0.13) or higher. At a net present value of B347,613/ha ($11,003.89), the price of oil palm must be B3.46/kg ($0.11) to be on par with rubber (third-grade rubber smoke sheet) at B70.00/kg ($2.22). With a price higher than B4.00/kg ($0.13), palm oil becomes very competitive and more profitable than rubber at a price of B70.00 (Table 17). Besides, the internal rate of return for oil palm is much higher than that for rubber, simply because oil palm can be harvested 3 years after planting, while rubber takes 6 to 7 years to mature before it can be tapped. Thus, under these conditions, in areas where both can be grown, oil palm is much preferred.

In summary, sugarcane is more attractive than cassava for the production of ethanol, whereas for biodiesel production, oil palm is outstanding. When oil palm is compared with rubber—a competing crop in the south—as the main source of income, oil palm is preferred. Jatropha production is negligible, so this crop is considered a distant alternative.

Ethanol Production

The production of ethanol is dependent on two major raw materials: molasses and cassava. Most ethanol plants use molasses, except for the Thai Nguan ethanol plant in Khon Kaen, which can produce 130,000 l/day from cassava feedstock (Table 18). Nine ethanol plants are in operation, with a combined capacity of 1.26 million l/day. The current actual production is about 0.98 million l/day, in line with the demand for gasohol which is estimated at about

Table 18: Ethanol Plants in Operation, 2008

		Ethanol Capacity ('000 liters/day)	
Name of Plant	**Feedstock**	**Registered**	**Actual**
Porn Wilai	Molasses	25.0	—
Thai Alcohol	Molasses	200.0	114.5
Thai Agro Energy	Molasses	150.0	121.0
Thai Nguan	Cassava	130.0	—
Khon Kaen Alcohol	Sugarcane and/or molasses	150.0	140.6
Petro Green (Chaiyapum)	Sugarcane and/or molasses	200.0	153.7
Thai Ethanol	Sugarcane and/or molasses	100.0	86.9
K.I. Ethanol	Sugarcane and/or molasses	100.0	101.4
Petro Green (Kalasin)	Sugarcane and/or molasses	200.0	260.7
Total	**...**	**1,255.0**	**978.8**

— = data unavailable, ... = column heading does not apply.

Note: The figures may not add up to totals due to rounding.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

10 million l/day. By the end of 2008, more ethanol plants will begin operations, based mainly on a feedstock of cassava.

In 2005–2008, sugar prices in the domestic and export markets were low. Not all molasses produced could be used in the country and a large portion was exported. When the government introduced gasohol, the sugar millers decided to invest in ethanol production, using surplus molasses as their main feedstock; hence the ethanol industry was initially based on molasses. Historically, cassava farmers are largely poor, scattered, and unorganized. They warrant special attention from the government, particularly during times of low cassava prices. This is why the government has insisted that cassava be given a considerable share of biofuel feedstock. In 2008, 10 ethanol plants with a combined registered capacity of 1.67 million l/day were under construction (Table 19). Most plants require cassava as their feedstock, in anticipation of continued low prices. However in January 2008 the situation began to change and cassava prices nearly doubled from their level a year earlier.

The ethanol industry has two options to accommodate rising feedstock prices. First, it can ask the government to further liberalize ethanol exports, since the overseas market for alcohol is huge. Second, it could

Table 19: Ethanol Plants Under Construction, 2008

Name of Plant	**Feedstock**	**Registered capacity ('000 liters/day)**
IEC Business Partners	Cassava	150.0
Fah Khuan Tip	Cassava	60.0
Ekarat Pattana	Molasses	200.0
Rachaburi Ethanol	Cassava and/ or molasses	150.0
Thai Rung Ruang	Sugarcane and/or molasses	120.0
ES Power	Cassava and/ or molasses	150.0
Sima Inter Products	Cassava	150.0
Sup Tip	Cassava	200.0
PSC Starch Products	Cassava	150.0
TPK Ethanol	Cassava	340.0
Total		**1,670.0**

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

further develop its downstream industries, which would add more value and provide investment and employment opportunities for private companies. In addition to its use in gasoline fuel mixtures and in the beverage industry in the form of alcohol, ethanol and by-products can be used in the cosmetics, drug, and paint industries. For example, propylene glycol from the alcohol family is an anti-hardening agent used in the food and drug industry, and is an ingredient in soaps, toothpastes, shampoos, and lotions. Likewise, isopropanol is mixed with nail enamel removers, adhesives, varnishes, and paints. These downstream industries are very promising. The government started to allow the export of alcohol, and in 2008 the volume exported totaled 14.37 million l. The three leading exporters were Khon Kaen Alcohol, Petro Green, and Thai Alcohol. The main markets were the Australia, the Philippines, and Singapore.

Biodiesel Production

Thailand's annual demand for biodiesel is expected to increase to 1.14 million l by the year 2012. This translates into a requirement of 0.39 mt of crude palm oil (CPO) in 2008, increasing to 1.06 mt of CPO in 2012.

The actual capacity of existing biodiesel plants in operation was about 0.5 million l/day in 2008 (Table 20). With the Thai Oleo Chemical, a subsidiary of the Petroleum Authority of Thailand, and Pure Biodiesel scheduled to begin operations in the second half of 2008, it is likely that the demand for biodiesel can easily be met. The total capacity of the Thai Oleo Chemical plant is 685,000 l/day and the capacity of the Pure Biodiesel plant is 300,000 l/day. However, two factors could upset this prediction.

Firstly, in a classic case of food versus feedstock, the demand for CPO from biodiesel plants increased at the beginning of 2008, resulting in a shortage of cooking oil. Biodiesel plants place orders for large quantities of palm oil ahead of schedule so as to meet the government requirement on diesel blending, thereby putting pressure on cooking oil. When cooking oil becomes scarce, consumers scramble to buy and hoard it all over the country in anticipation of price increases, thereby making the situation worse. The government inevitably has to raise the price of cooking oil, which is one of the sensitive commodities under government control. For more than a decade, palm oil used to be the cheapest cooking oil, but for much of 2008 it was as expensive as most other cooking oils.

Second, the registered capacity of the 10 biodiesel plants totals 2.48 million l/day (Table 20), outstripping the demand for pure biodiesel (B100) until 2010 (Table 3). The demand for B100 is expected to rise to 1.38 million l/day in 2010, which is well within the registered capacity of the 10 biodiesel plants. However, by 2011, all B2 will be abolished under the government regulation and replaced by B5. This will increase the demand for B100 to 3.02 million l/day, exceeding the 2008 capacity and precipitating a possible shortage in supply after 2010. By then, these biodiesel plants will need to secure additional supplies of feedstock, which will have to be drawn from new plantings of oil palm and other energy crops.

Table 20: Biodiesel Plants, 2008

	Biodiesel Capacity (liters/day)	
Name of Plant	**Registered**	**Actual**
Bioenergy Plus	100,000	6,336
Patum Vegetable Oil	300,000	221,122
Bangkok Alternative Energy	200,000	120,323
Green Power	200,000	56,444
A.I. Energy	250,000	75,454
Bangchak	50,000	5,355
Weerasuwan	200,000	1,099
Sun Tech Palm Oil	200,000	25,097
Thai Oleo Chemical	685,800	—
Pure Biodiesel	300,000	—
Total	**2,485,800**	**511,230**

— = data unavailable (started operation in the second half of 2008).

Source: Department of Energy and Trade.

The Supply Chain

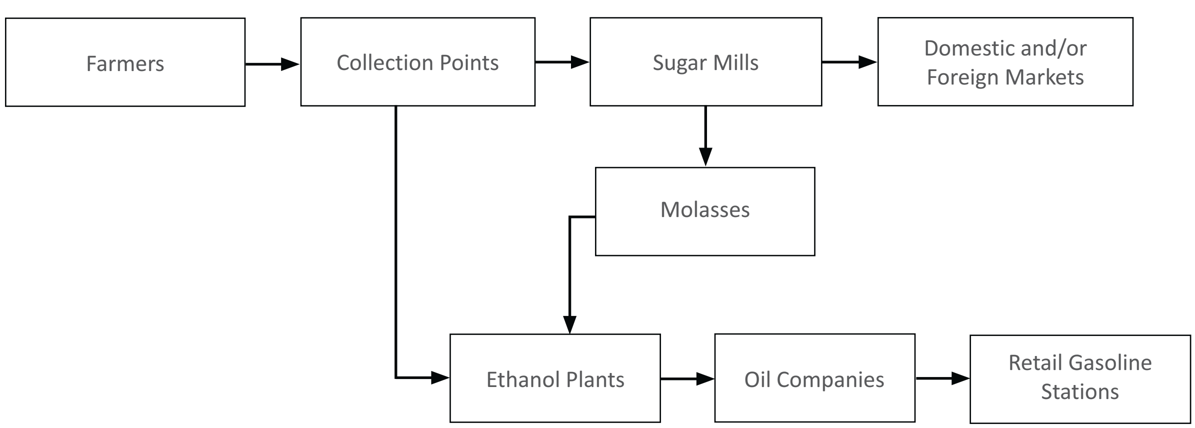
Biofuels present a range of possibilities for investment on varying scales for large and small investors. The major participants in the supply chain for ethanol and biodiesel production are farmers, middlemen, feedstock handlers, biofuel producers, and retailers. They fall into three categories: biofuel crop producers, biofuel producers, and biofuel retailers.

In the supply chain for ethanol production from sugarcane, the farmers deliver their sugarcane harvest to collection points (Figure 3). The harvest is then transported to sugar mills for processing into sugar. Molasses, a by-product, is sent to ethanol plants to be converted into ethanol, which is blended with benzene to produce gasohol 91 and gasohol 95 for distribution to retail gasoline outlets nationwide. Sugarcane can also be processed directly into ethanol. In Thailand, this process is still at an experimental stage, and is expected to be commercialized by 2010.

The supply chain for cassava is similar to that of sugarcane, except that cassava can be made into chips, pellets, and starch for food and non-food industries and for animal feed (Figure 4). It can be delivered directly to ethanol plants for processing and later blended with gasoline into gasohol by oil companies.

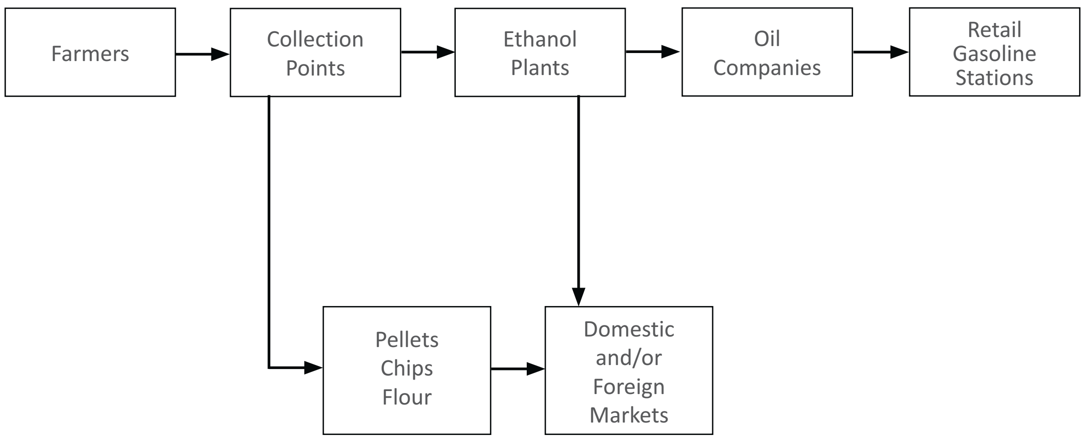
The supply chain for oil palm is shown in Figure 5. After collection from plantations, oil palm seeds are crushed at extraction plants to obtain crude palm oil (CPO). This is then sent to biodiesel plants or refineries to be blended with diesel for distribution to gasoline stations around the country. CPO can also be refined into cooking oil and glycerin. Glycerin can be further processed into ingredients for products such as cosmetics and soap powder.

Figure 3: The Supply Chain of Ethanol Production Using Sugarcane



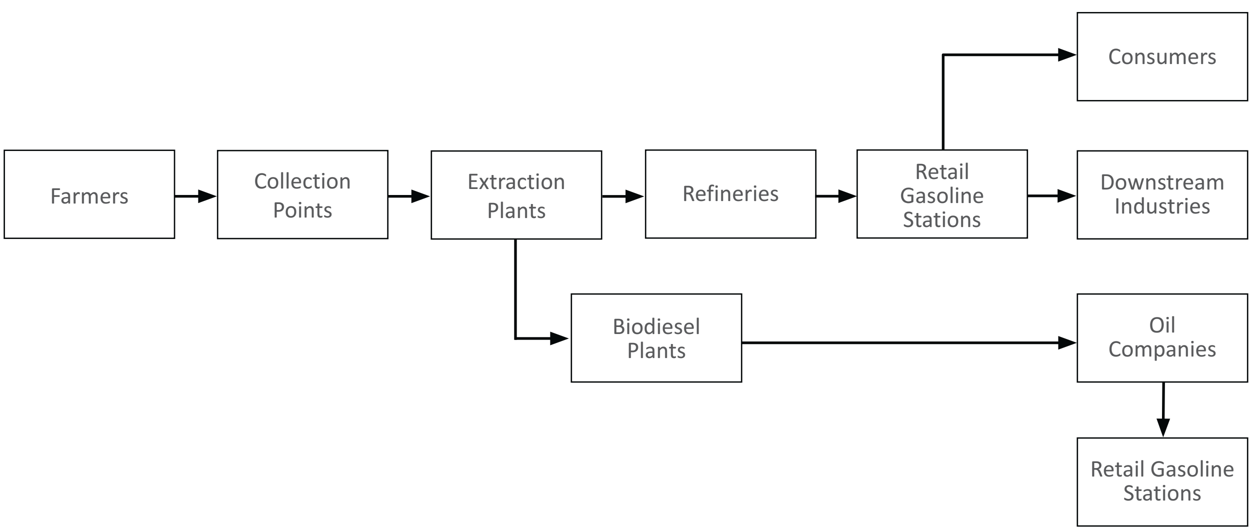
Source: the authors.

Figure 4: The Supply Chain of Ethanol Production Using Cassava



Source: Authors.

Figure 5: The Supply Chain of Biodiesel Production Using Oil Palm



Source: Authors.

Clustered Plantations

One business option for oil palm is to organize farmers into clusters of farms, with the aim of producing and processing oil palm into CPO for delivery to oil refineries or biodiesel plants. Clustered plantations can be an economically viable unit of investment for the production of CPO as they minimize transport costs.

While it was previously thought that the minimum size of a clustered plantation was about 10,000 hectares (ha), the government now believes that a cluster covering 1,000 ha may be able to realize an acceptable level of cash return, and remain sustainable in the long run. The smaller scale is also technically feasible, as oil palm can be crushed into CPO in small-scale facilities and transported to large biodiesel plants, taking into account the logistics of supply at each step of the operation.

The farmers can organize themselves into community oil extraction enterprises with a capacity of 1–5 tons per hour (t/hour). Each unit can cover small-scale oil palm plantations with a total size of 320–800 ha. It can produce animal feed and generate electricity from oil palm cake and other crop wastes.

Community-Level Biodiesel Production

Biodiesel offers an excellent opportunity for small investors. Small oil palm plantations can collectively gather and deliver oil palm fruits to the extraction plants for crushing and pressing into CPO. The extraction plants can be financed and owned by the village communities themselves. Conversion of CPO into biodiesel can take place within villages, with the support of the local government and the Ministry of Energy (MOE). The MOE provides technical assistance to organize the villagers into community enterprises which operate biodiesel plants by themselves. This has been successful in a number of communities. When the supply of palm oil is insufficient, these small biodiesel plants can process used cooking oil as an alternative feedstock. The communities can blend biodiesel with diesel, and sell it without much difficulty. The MOE has set up such biodiesel plants in 72 locations around the country (Table 21). Cooperative societies are another well-known form of farmers' organization. There are a few cooperatives of this type that apparently have done well in small-scale biodiesel production business ventures.

In Rayong Province, the Tubma Tambon Administrative Organization has set up a community enterprise chaired by Mr. Chawalkorn Chiablam, with the aim of producing biodiesel from jatropha. In 2008, the community planted 1,000 jatropha trees, from which 600–700 liters (l) of biodiesel are produced annually. Since jatropha production is scattered and its volume is not sufficient for processing into biodiesel, Mr. Chawalkorn decided to collect used cooking oil to use as feedstock. The biodiesel plant is small, with a capacity of 150 l/day, and was donated by the MOE for demonstration purposes. The biodiesel produced is sold commercially, but at a slightly lower price than the market price. Suppliers of jatropha seeds can have them crushed and converted into biodiesel, in which case they receive 1 l of biodiesel for every 6 kilograms (kg) of seeds. The proceeds from the sale of excess oil are retained as income for the community enterprise. In the case of used cooking oil, the conversion rate is 1 l of biodiesel from 1 kg used cooking oil at a cost of B12 ($0.38). The used cooking oil can also be sold to the biodiesel plant for B20/kg ($0.63/kg).

Table 21: Distribution of Small-Scale Biodiesel Plants under a Project of the Ministry of Energy, 2008

Region	Number of Plants
North	18
Central	15
Northeast	17
South	20
East	2
Total	**72**

Note: The Ministry of Agriculture and Cooperatives has also distributed 28 pilot plants to community enterprises.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

Small biodiesel plants are relatively inefficient, but nevertheless require a regular supply of feedstock. More often than not, they lie idle due to a lack of raw materials. They also require highly skilled management to run efficiently. Thus, before any investment decision is made, it is imperative to ensure that sufficient raw materials and skilled staff will be available.

This argument also applies to biodiesel plants that use jatropha as a feedstock. Although production in large-scale facilities is more efficient, biodiesel from jatropha can be produced by community enterprises. These facilities can also make use of the large amount of residue in the form of seedcake, which is burned to provide electricity to the processing plant itself, and any surplus can be sold to the electric power grid under the Electricity Generating Authority of Thailand.

Extension Beyond the Country's Borders

The countries of the Greater Mekong Subregion (GMS) are very diverse in terms of resource endowment, political and social systems, bureaucratic structure, infrastructure development, and availability of skilled workers. Such diversity can be explored and integrated into a framework in which GMS countries can both individually and collectively reap the benefits. Biofuel crops can be produced in one country and then processed in another country. Marketing of biofuels can take place in yet another country. Such arrangements can benefit all countries concerned. Contract farming involving tomatoes and baby corn illustrates this kind of arrangement. The vegetables are grown in the Lao People's Democratic Republic (Lao PDR) and exported to Thailand for canning. A portion of the canned product is then exported for sale in the Lao PDR and other countries. Similarly, CPO can be produced in Cambodia, converted into biodiesel in Thailand, and then sold in the Lao PDR. Jatropha can be produced in Myanmar, and then exported in the form of seeds into Thailand for large-scale oil extraction, and subsequent biodiesel production. Large-scale extraction plants are more efficient and the oil is of higher quality.

Thailand's GMS neighbors are already involved in the production of bioenergy crops. Myanmar has adopted a policy of jatropha expansion throughout the country and the trees started to bear fruit on a large scale in 2008. Jatropha is also grown in Cambodia and the Lao PDR, although in limited quantities. Its oil is being extracted using small seed presses, and used to run farm machinery. Currently, the scale of these activities is limited, and when expanded to a commercial scale, these producers will be required to meet minimum standards. The cultivation of oil palm in Cambodia, the Lao PDR, and Myanmar has had limited success. Myanmar has been producing sugarcane for some time. In 2004, 0.28 million ha were planted with sugarcane, yielding 7.00 million tons. In 2009, the Lao PDR will start the first mill to produce sugar, not ethanol, from sugarcane. The area of land planted to sugarcane in the Lao PDR was 0.1 million ha in 2006, and about 0.22 million tons were harvested. Myanmar and the Lao PDR produce cassava, but neither the level of production nor the logistical networks have reached the stage where further investment for the production of tapioca starch is justified. The juxtaposition of Cambodia, the Lao PDR, Myanmar, Thailand, and Viet Nam, gives an insight into the potential for cross-border trade and investment in biofuels and the potential for integrating biofuels production, processing and distribution in the GMS. Thus, intra-regional trade and investment provides another promising business option for biofuel development.

Policy Support for Biofuels

National Policy

Overall National Policy Objectives

The objectives of Thailand's biofuels policy include (i) to sustain a degree of energy security, particularly in gasoline and petroleum products; (ii) to develop new markets for the main biofuel crops—sugarcane, cassava, and oil palm—to increase investment opportunities for farmers and improve their incomes; (iii) to provide assistance to ensure the economic sustainability of sugarcane farmers at times of low sugar export prices; and (iv) to introduce an alternative crop under the Sufficiency Economy Principle, by promoting the production of jatropha among small and marginal farmers (footnote 1).

Policy toward Countries of the Greater Mekong Subregion

The policy toward countries of the Greater Mekong Subregion (GMS) with regard to biofuels can be divided into opportunities for trade and investment, and contract farming. Trade and investment among GMS countries over the past decade has enabled biofuel crops to be grown in countries where land is sufficient and where farmers seek new farming opportunities as a source of extra income. Through competitive advantage, crops can be produced in one country and processed in another, where infrastructure facilities are more developed and cost-effective. This outward-looking policy of biofuel development illustrates a win–win situation for GMS countries. Under these circumstances, the degree of dependence on the importation of fossil fuels from outside the region will be lessened.

For these reasons, GMS countries have warmly welcomed contract farming as a means to meet the demand for, and supply of, farm commodities. Thailand has tried unsuccessfully to formulate rules and regulations governing contract farming with GMS countries; however, this may not be a prerequisite for promoting contract farming in the subregion, as it is already taking place without much government support or intervention. Rather than seeking to control contract farming, the government can devote its efforts to facilitate it and help solve problems that the practice may encounter. In so doing, contract farming is likely to have an important bearing on the long-term well being of the rural poor in the subregion.

Oil Pricing

Through the operation of the Oil Fund, the government subsidizes the difference between the actual cost and the selling price of fuels, hence minimizing the impact of high oil prices on the public, particularly from retail gasoline stations and household liquefied petroleum gas (LPG). The Oil Fund was established by law to serve as a mechanism to prevent oil shortages and to stabilize retail oil prices when world prices rise. It determines the wholesale oil prices at the refineries and the final retail oil prices and fixes marketing margins for the sale of oil. It determines and collects the levy from oil and natural gas producers and importers. The Oil Fund can be used to compensate losses incurred by these parties, as well as oil and national gas exporters and LPG retailers.

Energy Conservation

The government has launched a series of campaigns to reduce energy consumption through example-setting by government offices nationwide and the sponsorship of energy-saving programs in the private sector. All government vehicles are required to use gasohol only, and the temperature in air-conditioned government offices is set at 25 degrees Celcius or higher. Fluorescent light bulbs have been sold nationwide at a low price. These measures are financed by the Energy Conservation Fund,[7] which receives funding from the Oil Fund and direct government support.

Feedstock Policy

Biofuel crops have received a degree of government support since the 1990s because these crops have seen fluctuations in prices and have traditionally been largely dependent on the export market long before the biofuel policy was formulated. The government continues to fund research on varietal improvement and the distribution of better planting materials to farmers. At times of low cassava prices, the government introduces a pledging scheme to assist the growers.[8] Current policy for the three main biofuel feedstocks is as follows:

(i) **Sugarcane.** The Ministry of Agriculture and Cooperatives (MOAC) aims to raise sugarcane productivity without expanding the current area of about 0.97 million hectares (ha). The yield in 2006 was only 49.4 tons per ha (t/ha) due to drought. Normal yields are about 62.5 t/ha, and the MOAC hopes to raise productivity to 93.8 t/ ha by 2010.

(ii) **Cassava.** In 2006, the area under cassava was 1.07 million ha and the yield was 22.6 t/ha. The policy of the MOAC is to maintain the same cultivated area and increase production through the use of better varieties and more efficient farm management practices to achieve a target yield of 29.4 t/ha in 2010.

(iii) **Oil palm.** In 2006, oil palm plantations covered 0.51 million ha and production was 6.72 mt. With steady expansion they are expected to reach 0.91 million ha by 2012. Given that oil palm is very promising both as a food and a feedstock, production will expand to reach a level at which the local demand for edible oil and biofuels can both be satisfied.

Investment Policy

The Board of Investment Promotion provides special privileges to producers of ethanol and biodiesel in the form of zero taxes on imported equipment and machinery, and zero income tax for 8 years.

Biofuel Production Policy

In 2000, the cabinet approved the biomass ethanol project, with the aim of encouraging private investment in ethanol production. In the same year, 24 investment permits were issued, with a combined production capacity of 4,115,000 liters per day (l/day). Another three investment permits to produce and export, with a total production capacity of 595,000 l/ day, were issued in the following year. By 2006, it became apparent that the construction of the plants was delayed, allegedly because of uncertainties surrounding the government-controlled price of ethanol. In order to encourage greater competition among investors, and to ensure a sufficient supply of ethanol, the government lifted the ceiling on investment permits and encouraged the rest of the private sector to invest. Consequently, 18 more permits for a total output of 5,730,000 l/day were granted on 14 September 2006.

For the production of biodiesel, the government has a policy of nonintervention, and those interested in such a venture could submit an application to the Department of Industrial Plants, Ministry of Industry. The Energy Policy Committee appointed two subcommittees to oversee the production of ethanol and biodiesel. In addition, on 15 January 2008, the cabinet approved a government order to set up a National Oil Palm Policy Committee to formulate a comprehensive framework for oil palm development.

The Ministry of Energy (MOE) and other related agencies have sought to promote the use of feedstock to produce bioenergy without jeopardizing food

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[7] The Energy Conservation Fund was created in 1992 to facilitate investment by government agencies in energy conservation and in mitigating the environmental impact of energy conservation. It also gives grants to government authorities, state enterprises, academic institutions, and private organizations for projects on energy conservation and related environmental problems.

[8] The pledging scheme is common in Thailand for a number of commodities such as paddy, cassava, and maize. In the past, the government incurred heavy losses in such schemes and corruption was allegedly widespread. It is seeking to improve the process so that it can operate more efficiently, with transparency and good governance.

supply. In particular, biodiesel production will use excess crude palm oil (CPO) left over from domestic consumption of cooking oil, and will be encouraged to expand only when new plantations come into production.

Biofuel Use Policy

The MOE is responsible for promoting the use of biomass energy, including biofuels. It placed a target on the use of ethanol to substitute for methyl tertiary butyl ether in 95 octane gasoline and also to substitute part of 91 octane gasoline at the rate of 1.00 million l/day in 2006, to be increased to 3.00 million l/day by 2011. In 2007, the MOE reduced the target to 2.40 million l/day, due to the economic slowdown and the price effect of gasoline consumption, wherein its demand decreases in response to a price rise.

The target for biodiesel is to blend 5% B100 with diesel fuel for the whole kingdom by 2011—equivalent to 3.96 million l/day of B100. By 2012, the blending rate of biodiesel would be increased to 10%, or 8.50 million l/day of B100. However, for much the same reasons as in the case of ethanol, the target for 2011 was revised downwards to 3.02 million l/day of B100.

Government Measures to Sustain Biofuel Production and Use

Feedstock Production

The price of cassava increased from B1.20/kg ($0.03) in January 2007 to B1.90/kg ($0.05) in December of the same year. Consequently, cassava farmers harvested and sold the roots when the plants were only 7 months old. This resulted in shortfall in production of 20%–25% compared to the predicted level. The MOAC formulated an action plan for cassava development from 2008 to 2010 which aims to raise production to the level where it meets domestic needs and export demand, and maintain price stability. In the plan, the area under cassava will be kept at 1.18 million ha, and the yield will be raised from 23.1 t/ha to 29.3 t/ha during the same period. This will be achieved through the adoption of the following measures:[9]

(i) **Increase in productivity.** In areas where the average yield is over 23.1 t/ha productivity increases will be promoted through the use of quality cuttings for planting, breaking of the hardpan in the surface soil, soil and land improvement, and weeding and harvesting at appropriate times. In other areas, the government will encourage the use of quality cuttings and participatory technical transfer.

(ii) **Adding value.** The production of clean cassava starch and cassava chips without impurities will be encouraged to add value to the crop.

(iii) **Research and development.** Field experiments will be carried out to select better varieties for ethanol production and varieties with high starch content. More research will be conducted on production technologies, agricultural machinery, and product development. Several research institutions, e.g., Kasetsart University, Suranaree University of Technology, and the Upland Crop Research Institute of the Department of Agriculture at the MOAC, are identifying ways in which the yield of cassava can be increased. In some cases, private firms can finance the research. In addition, different farm management techniques are being tested. Various mixes of chemical and organic fertilizers are being tested in different soil conditions. Alternative plowing methods are being analyzed to determine their effect on yield, and agricultural machinery for planting and harvesting is being improved. Handling at collection points is often time-consuming and labor-intensive. This needs to be improved by the use of mobile conveyor belts and cranes.

(iv) **Marketing potential.** Domestic consumption and uses will be expanded. Efforts will be made to maintain the existing export markets and to search for new ones. Product quality will be improved and branding encouraged.

About 30% of oil palm grown is of low quality because inferior varieties have been used and the trees are more than 20 years old. In accordance with the 2008–2012 Oil Palm Industrial Development Plan,[10]

[9] Office of Agricultural Economics. 2008. *Biofuel Crop Production.* Bangkok. Thailand. (mimeo.).

[10] Ministry of Agriculture and Cooperatives. 2007. *Oil Palm Industrial Development Plan (2008–2012)*. Bangkok. Thailand.

the MOAC will encourage farmers to grow oil palms in suitable soils at the rate of 80,000 ha/year in new areas and 16,000 ha/year in old plantations. The Bank for Agriculture and Agricultural Cooperatives (BAAC) will provide farmers with low-interest loans of B46,000–B80,000/ha ($1,456–$2,532), with a repayment period of no more than 15 years. On 22 November 2007, the MOE and the BAAC resolved to provide a low-interest B7,000 million loan to farmers to grow oil palm for 10 years at a minimum rate of return of –0.5%.[11] Funding for the loans would come in equal share from the Oil Fund and the BAAC.

Bioenergy Production Measures

The MOE has issued a quality control measure for ethanol, gasoline, and gasohol to build consumer confidence. Specifications for B100, for example, must follow the standard set by the Department of Energy Trade. The MOE has also stipulated the pricing of biodiesel and ethanol, as agreed by the producers, oil companies, and government authorities. This assures consumers of fair prices. The biodiesel price is dependent largely on the Malaysian price of CPO, whereas the price of ethanol uses the import price parity principle, in which the Brazilian price of ethanol is the major determinant. These prices are intended to enable domestic producers to be competitive.

Measures for Bioenergy Use

In 2003, the government set an example by instituting the use of gasohol in government vehicles throughout the country. The pricing of biofuels at the level below that of fossil fuels was structured via varying levies paid to the Oil Fund so as to maintain price differentials at retail outlets in favor of biofuels. At the request of the MOE, the motor industry and the oil companies assured the public that vehicles, particularly recent models, could use gasohol without causing any damage to the engines. This helped increase consumer confidence in bioenergy use.

Environmental Measures

Ethanol plants are required to submit their plan for a wastewater treatment system along with their application for production permits. Provincial authorities have also been instructed to closely monitor wastewater discharges. In addition, the Ministry of Natural Resources and Environment will conduct air pollution tests on cars and motorcycles that use gasohol.

Investment Measures

The Government of Thailand, in contrast to some other countries, does not provide financial support to bioenergy producers. However, the MOE designated a revolving fund to help entrepreneurs make investments to replace the use of fossil fuel with alternative fuel sources in their plants (for example, the production of biogas from wastewater, and the generation of electricity from biomass in palm oil extraction plants). Biodiesel plants cannot receive financial support from the MOE because they produce biodiesel for sale and not for their own use. Each project will receive no more than B50 million ($1.58 million) at an interest rate of up to 4%.

Policy Implications of Feedstock Supplies and Biofuel Pricing

Trend of Feedstock Supplies

The early harvesting of cassava to take advantage of high prices results in a lower yield and inferior starch content. Cuttings used for future plantings are too young and produce stunted plants in the following season. Thus, the projected yield and target production may not be achieved.

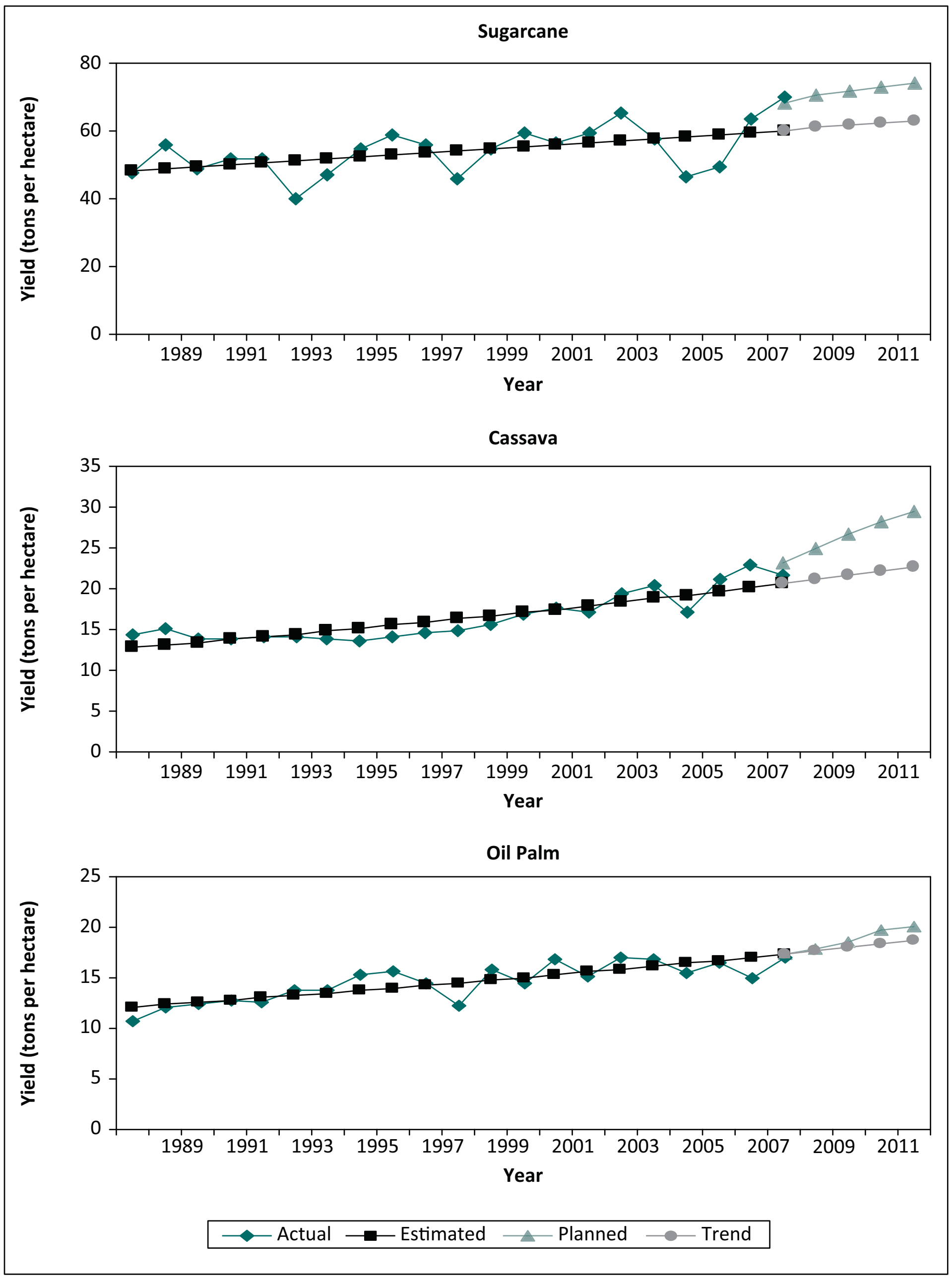
In the case of oil palm, it was assumed that production would be used for edible oil first, and any excess would be converted into biofuel. This assumption proved to be incorrect, since not only does the government lack the means to control palm oil stocks, but it has also liberalized the export trade in edible oil. Furthermore, to inform consumers of higher cooking oil prices, the government announced in November 2007 that edible oil prices would be allowed to increase at a future date (effective 1 January 2008). This announcement had the undesired effect of encouraging many consumers, including the food industry (which relies heavily on palm oil as a product ingredient) to increase their stocks of edible oil, causing shortages in the market by January 2008. The situation still prevailed months later, even though the government allowed the importation of 30,000 t

[11] The minimum rate of return in 2008 was 7%.

of CPO in late January 2008. Meanwhile, biodiesel refineries such as Pure Biodiesel and Thai Oleo Chemicals started to operate with an annual combined capacity of 600,000 t of CPO further increasing the demand for palm oil as a feedstock.

In light of this trend, if the government cannot find a way to prevent this occurrence, there is a real danger that the biodiesel policy is flawed and that conflicts between food and fuel will threaten food security. In such a case, the situation of the poor will deteriorate.

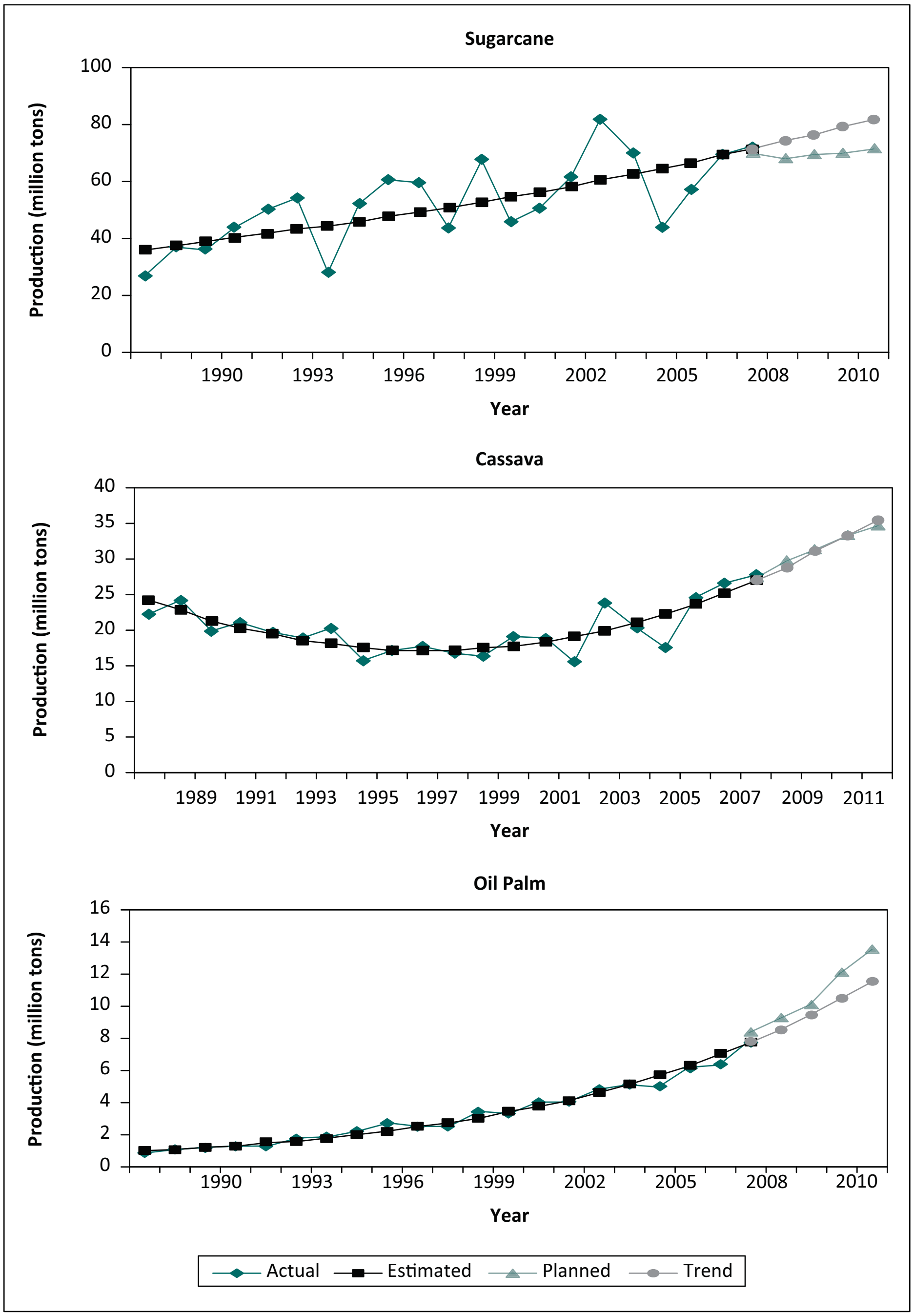
Figure 6: Trends in the Yield of Sugarcane, Cassava and Oil Palm (tons per hectare)



Note: Estimated figures and trend are from time series statistical analysis.

Source: Actual and planned data are from the Office of Agricultural Economics.

Figure 7: Trends in the Production of Sugarcane, Cassava and Oil Palm (million tons)



Note: Estimated figures and trend are from time series statistical analysis.

Source: Actual and planned data are from the Office of Agricultural Economics.

The planned yield targets of biofuel crops, as set in the commodity strategic development plans, appear to be high, compared with their past performance (Figure 6). The trend in yield is lower than the planned target in all cases. The difference lies in the assumption in the commodity strategic development plans that production will increase with no expansion in acreage for sugarcane and cassava. But if past performance is a guide, then the yield target as planned will not be easy to achieve.

Comparing the trend in the production of these crops (Figure 7) and the planned target, on the other hand, shows mixed results. The trend seems to be higher than the planned target for sugarcane and cassava, but lower in the case of oil palm. It appears that production can be increased, not so much by increases in yield but by expansion in acreage, either at the expense of other crops or by bringing idle land into cultivation. This calls for a revision of the commodity strategic development plans for sugarcane and cassava. As for oil palm, since new plantations will take at least 3 years to come into production, the situation should be monitored closely and the plan adjusted accordingly.

Pricing of Biofuels

The government formulated the pricing structure of biofuels in consultation with biofuel producers and oil companies. The price of ethanol at the factory gate is set by the following formula:

Price of ethanol = Brazilian price + logistics + insurance + loss + survey

The price of ethanol is based on the Brazillian price as Brazil is the world's largest ethanol producer. The other factors, such as logistical arrangements and insurance, reflect an additional cost which would be incurred if ethanol from Brazil is imported into Thailand. In this respect, ethanol in Thailand is considered to be competitive with imported ethanol.

The price of B100 is drawn largely from the Malaysian CPO price, which can be regarded as the world price. It is determined by the following formula:

Price of B100 = 0.97(price of CPO) + 0.15(price of methane) + 3.32

In this formula the coefficients reflect the extent to which the price of B100 is determined by the price of CPO and methane. The addition of 3.32 covers the conversion cost of producing B100 from CPO.

When the agreement was made, all parties appeared to be satisfied; however, disagreements emerged when the price of feedstock increased, and the level of consumption of biofuels was insufficient. Some factories experienced a glut of ethanol, whereas biodiesel companies had to compete to acquire the quantity of CPO required by their plants. The result was a shortage of supply to meet the demand for cooking oil.

The government initially set the price differential at B1.50/l ($0.05) to encourage motorists to switch to gasohol. Under this model, whatever the price of gasoline, the gasohol counterpart would be B1.50/l ($0.05) cheaper. However, this was not sufficiently attractive to the majority of consumers who feared that gasohol might damage car engines, as the price difference was so minimal that the perceived risks outweighed the gains. With an excess of ethanol supplies and free entry into the ethanol industry, the price of gasohol fell and the price difference increased to more than B4.00/l ($0.13), instead of B1.50/l ($0.05). For example, gasoline 95 was sold at B42.09/l ($1.33), whereas gasohol 95 was offered at B37.39/l ($1.18) (Table 22).

This new price differential had a major impact on the preferences of motorists. The consumption of gasohol 95 and gasohol 91 more than doubled from 3.50 million l/day in 2006 to 7.28 million l/day in February 2008, and reached 7.60 million l/day in July 2008. The consumption of E20 reached 0.89 million l/day by July 2008. Consumption of gasoline 91 and gasoline 95 fell from 16.26 million l/day in 2006 to 12.13 million l/day in February 2008. By July 2008 consumption had dropped to 9.10 million l/day, equivalent to just over half the level of 2006.

The rise in the price of diesel caused motorists to avoid unnecessary travel and to buy gas-propelled vehicles instead. The number of such vehicles is, by one estimate, at least 1 million, whereas the official record shows only 0.3 million. The level of diesel consumption fell from 50.19 million l/day in 2006 to about 40 million l/day by July 2008.

Table 22: Retail Gasoline Prices in Bangkok on 28 June 2008

Type of Gasoline	Price	
	baht/liter	$/liter
Gasoline 95	42.09	1.33
Gasohol 95	37.39	1.18
Gasoline 91	40.99	1.30
Gasohol 91	36.59	1.16
E20	36.09	1.14
Diesel (B2)	42.64	1.35
B5	41.14	1.30
B10	41.14	1.30

B2 = diesel containing a 2% blend of biodiesel, B5 = diesel containing a 5% blend of biodiesel, B10 = diesel containing a 10% blend of biodiesel, E20 = gasoline containing a 20% blend of ethanol.

Source: Petroleum Authority of Thailand.

The pricing of biofuels, therefore, exerts a strong influence on the industry and consumer preference. Although the government has maintained its market-based liberalization policy on biofuel prices, the fact is that pricing is rigidly regulated, and criticism can be laid on the use of the Brazilian price of ethanol and the Malaysian price of CPO as given. In the real world, prices are determined not only by market forces but also by a number of nonmarket factors. Market forces alone extend beyond biofuel suppliers and consumers. They can represent the need for feed and the right to food as well.

In order to ensure its availability to the consumers at an affordable price, cooking oil is more often than not controlled or regulated. On the other hand, the government has to keep CPO prices high enough for the growers to receive reasonable returns for the crop. Oil companies must take CPO prices as given and bear the burden of the decision when it comes to blending. In 2009, B2 will not pose any problem, because diesel requires only a 2% B100 blend. In 2011, when B5 replaces B2, the problem of price distortion will become more serious. It will worsen still further when blending with greater amounts of B100 comes into force. The preferred course of action is to fix the price of ethanol and B100 for a specified period of time and to institute a mechanism by which the price can be assessed and revised from time to time. The clear advantage of fixing the price of biofuel for a period of time is that this will minimize the investment risk from fluctuations in the price of biofuels. This is important as biofuel investment is already a venture into the unknown.

Initially, the pricing of ethanol and B100 was thought to be reasonable, as it reflected world prices and would therefore allow the domestic industry to compete against foreign imports. However, the pricing of biofuels did not take into account the domestic price level—particularly the high price of feedstock. Oil palm and cassava prices have skyrocketed, undermining the competitive position of biofuel producers. The effects can have repercussions in the wider economy, for instance through the increased price of cooking oil, the cheapest and most widely consumed of which is edible palm oil. Consumers are now subject to the whims of oil refineries and food manufacturers.

Ethanol producers enjoy a better position, as they can switch from cassava to sugarcane and molasses as their feedstock. However, the level of gasohol consumption has failed to meet targets and, as a result, there is a glut of ethanol. The government eventually lifted the export restriction and allowed ethanol to be exported. This decision undermined the original purpose of introducing ethanol into gasoline, i.e., the reduction of oil imports. Nevertheless, the notion that regulated pricing of ethanol and biodiesel must be eliminated and stakeholders negotiate among themselves may be self-destructive. While liberalization appears to be the best solution in a perfect world, it has no place in the real world of oligopolies and monopolies.

Conclusions and Recommendations

Thailand has made substantial progress towards a biofuel development program in which energy crops are produced and converted into fuels for transport. The biofuel policy has been formulated and revised several times. The development of biofuels depends on a number of participants, including farmers, urban dwellers, and automobile manufacturers. It involves private–public partnerships, in which the government sets the example and the private sector follows suit after a series of consultations. Investments are needed at many points in the supply chain, and must come largely from the private sector, whose constituents range from individual farmers to oil refineries.

Although biofuel is on the national agenda and government authorities are required to adhere to its targets and goals, implementation of the program has not been smooth. It was extremely difficult to achieve coordination among various government agencies and ministries. Targets were formulated with inputs from all parties, but they failed because of a lack of preparedness, insufficient support, and inadequate finance. In addition, the government was more concerned with the preferential treatment of biofuels and fossil fuels, with a view of replacing oil imports in the long run, and consequently paid too little attention to competing uses between food and feedstock. It therefore failed to ensure national food security, as can be witnessed from the nationwide shortage of cooking oil, spearheaded by palm oil in early 2008.

For future biofuel crop development, priority should be placed on sugarcane for bioethanol production and oil palm for the production of biodiesel. Cassava is also a viable alternative, although it has multiple uses and volatile pricing. Jatropha can be grown among small and marginal farmers, and is ideally suited to the concept and principle of sufficiency economy.

In the light of these conclusions, eight recommendations are put forward:

(i) **The national biofuel policy must be clear and well thought out, with strong government commitment.** The direction of the national biofuel policy will be affected to a large extent by developments in the automobile industry in 2009–2012. In 2007, the government lowered the excise tax on the eco-car—a small subcompact vehicle with high fuel efficiency. In 2008, the government did the same for motor vehicles which run on E85—a blend of 85% ethanol and 15% gasoline. Such measures could increase demand for ethanol considerably. The government also favors the use of natural gas for vehicles. In 2007–2008 it subsidized the installation of alternative fuel conversion systems, and offered soft loans to automobile owners for the conversion of their vehicles to natural gas. To reduce the use of liquefied petroleum gas (LPG) in cars, it tightened the regulations on installation by ordering all installation companies to adhere strictly to engineering standards. This stems partly from the fact that the LPG price is heavily subsidized (as it is widely used as cooking gas) and also that it has to be imported, whereas natural gas for vehicles is produced from domestic sources. Despite this, LPG remains popular. The national framework for biofuel development will need to be adjusted to keep pace with mainstream developments.

(ii) **Small and medium-sized enterprises should be promoted.** Since biofuel crop producers are generally small, efforts should be made to promote the development of small and medium-sized enterprises which can engage in various stages of biofuel production. The lack of technology and management skills can be overcome through further research and training. This, in particular, will help expand oil palm production by small farmers in new areas.

(iii) **Public–private partnerships should be fostered and strengthened.** Complaints from car manufacturers regarding the government's shifting stance on biofuels are a reminder that close, timely consultation is needed between the government and the industry before any concrete decision is made. This action can help ensure that deadlines do not have to be extended, or targets revised (as already occurred in the past) because they were later found to be inappropriate or impossible to achieve.

(iv) **Private investment along the supply chain in Thailand and within the Greater Mekong Subregion should be encouraged.** Taking into consideration the importance of cross-border trade and the interwoven relationships among neighboring countries, private investment along the supply chain in Thailand and within the Greater Mekong Subregion should be encouraged. In new oil palm areas, the government may need to provide public infrastructure for potential investors to set up processing facilities. In managing more efficiently the supply chain and ensuring a continuous flow of biofuel supplies, Thailand should consider keeping control of stocks of biofuels. Since ethanol is sometimes in surplus, its export to neighboring countries should be encouraged. In cases where the feedstock produced by a country is insufficient to warrant the construction of a biofuel plant, cross-border trade can benefit both Thailand and neighboring countries.

(v) **More effective coordination among government ministries and agencies is needed.** Biofuels development falls within the responsibility of several government ministries. Projects and programs must be made available in detail so that there is effective coordination among government ministries and agencies to ensure their successful implementation. For instance, when it becomes clear that the targeted increase in the yield of cassava may not be achieved, concerned government agencies can get together to refine and reorient their programs and avert a fall in cassava production.

(vi) **The government must take all precautions to maintain food security.** The quantity of feedstock available for biofuel production was calculated on the understanding that domestic consumption and exports had been taken into account. However, this does not correspond to the real world in which prices determine supply and demand. When oil prices are high and rising, biofuel manufacturers can bid up the price of the feedstock and deprive the food industry of the share it requires. The price of the commodity can, and does, directly affect the level of demand for food, and hence domestic consumption. Food security, especially for those in the low income bracket, may be threatened. The development of biofuels cannot be allowed to compromise the supply of food or make it too costly for the average consumer.

(vii) **More research and development into energy crops is needed.** The national framework for biodiesel development requires substantial crop yield increases. Research and development into energy crops will be needed to realize this plan. For cassava, improved varieties should have higher starch content and preferably a shorter maturity time. The choice between chemical and organic fertilizers will have to be made, including the amount to apply. Both types of fertilizers may need to be applied to cassava to increase its yield. Mechanization is still low, particularly in planting and harvesting, but will have to be increased to avoid labor shortages and to achieve timely execution.

Varietal development is crucial for higher palm oil production. The response to water application from irrigation facilities and fertilizer treatment will help increase the body of knowledge and can help achieve biofuel production targets. Varietal improvement is also needed on a continuous basis for sugarcane. Mechanization in sugarcane plantations is still limited and must be expanded in the light of labor shortages. Biological control of pests and plant diseases is practiced, but it needs to be carried out in a timely manner to quickly contain pests. New biological pest control methods with greater effectiveness must be developed. Improved varieties of jatropha which thrive in particular soil and climate conditions must be developed to achieve higher yields and faster ripening. Production techniques also need to be gradually improved. The use of irrigation and fertilizers can improve the yield of jatropha, but the costs and benefits of the investment have to be assessed to determine whether it is worthwhile. A value chain analysis also needs to be conducted on biofuels, particularly oil palm, to identify major factors that can facilitate or impede the value chain.

(viii) **The national biofuel policy body should be strengthened.** The National Energy Policy Board which is directly in charge of the biofuel policy should be strengthened to enable a more comprehensive, careful, and deliberate assessment of policy options and their impacts on the economy. Such a body must be equipped with appropriate policy tools, and the measures it adopts must be adhered to and implemented expediently.

Appendix: Planted Areas of Sugarcane, Cassava, and Oil Palm Interpreted from Landsat Images, and Production Estimated from the Crop Simulation Model

Table A1: Sugarcane Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: North Thailand

	2005		2006		Increase or decrease	
Province	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
Chiang Mai	164	0.01	2,860	0.15	2,696	0.14
Kampangpet	43,874	3.24	40,882	3.02	(2,992)	(0.21)
Lampang	3,821	0.20	5,113	0.26	1,292	0.07
Nakon Sawan	65,593	5.62	66,960	5.74	1,367	0.12
Pichit	3,339	0.25	3,619	0.27	280	0.02
Pitsanuloke	4,592	0.40	6,607	0.58	2,016	0.18
Sukhothai	24,041	2.18	24,461	2.21	421	0.04
Tak	384	0.02	485	0.03	101	0.01
Uthai Thani	25,425	2.21	28,134	2.45	2,709	0.25
Uttaradit	2,564	0.13	3,789	0.19	1,225	0.06
Total	**173,797**	**14.26**	**182,912**	**14.90**	**9,115**	**0.68**

( ) = negative number, t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table A2: Sugarcane Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Central Thailand

Province	2005		2006		Increase or decrease	
	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
Angthong	1,075	0.10	1,125	0.10	50	0.01
Chainat	10,276	0.68	10,131	0.67	(145)	(0.01)
Kanchanaburi	83,753	5.99	83,840	6.03	86	0.04
Lopburi	68,613	3.88	68,388	3.87	(225)	(0.01)
Nakon Pathom	8,964	0.80	9,476	0.85	511	0.05
Petchburi	3,694	0.22	4,796	0.28	1,101	0.06
Prachuab Kirikhan	5,513	0.31	5,832	0.33	318	0.02
Rachaburi	21,521	1.57	22,903	1.68	1,382	0.11
Saraburi	2,227	0.16	1,947	0.14	(279)	(0.02)
Supanburi	75,830	6.00	77,859	6.16	2,029	0.16
Total	**281,466**	**19.71**	**286,295**	**20.11**	**4,830**	**0.41**

( ) = negative number, t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table A3: Sugarcane Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Eastern Thailand

Province	2005		2006		Increase or decrease	
	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
Chachoengsao	8,389	0.47	8,530	0.48	141	0.01
Chantaburi	1,817	0.09	2,291	0.11	475	0.02
Cholburi	19,349	1.34	19,928	1.38	578	0.04
Prachinburi	2,197	0.11	1,986	0.10	(211)	(0.01)
Rayong	1,322	0.09	1,742	0.11	420	0.03
Srakaew	19,801	1.25	22,915	1.45	3,114	0.20
Total	**52,874**	**3.35**	**57,392**	**3.63**	**4,517**	**0.29**

( ) = negative number, t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table A4: Sugarcane Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Northeast Thailand

Province	2005		2006		Increase or decrease	
	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
Amnatcharoen	1,343	0.11	1,506	0.12	163	0.01
Burirum	14,861	0.88	15,195	0.90	334	0.02
Chaiyaphum	55,889	3.30	57,668	3.41	1,780	0.11
Kalasin	43,180	3.18	44,885	3.34	1,705	0.15
Khon Kaen	76,059	4.51	77,835	4.62	1,776	0.11
Nakon Panom	530	0.04	676	0.05	146	0.01
Nong Khai	3,735	0.24	3,939	0.26	204	0.01
Nongbua-Lumphu	5,615	0.38	5,110	0.35	(505)	(0.03)
Roi Et	5,950	0.58	6,251	0.61	301	0.03
Ubonracha-thani	360	0.03	481	0.04	121	0.01
Udon Thani	83,007	5.14	86,473	5.34	3,467	0.20
Yasothon	2,058	0.16	2,210	0.17	152	0.01
Total	**292,586**	**18.55**	**302,228**	**19.21**	**9,643**	**0.64**

( ) = negative number, t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table A5: Cassava Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Central Thailand

Province	2005		2006		Increase or decrease	
	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
Chainat	10,444	0.21	11,311	0.22	867	0.02
Lopburi	14,226	0.38	15,105	0.40	879	0.02
Petchburi	257	0.01	357	0.01	99	0
Rachaburi	15,324	0.38	16,744	0.42	1,420	0.04
Saraburi	6,171	0.16	7,325	0.19	1,154	0.03
Supanburi	4,189	0.09	5,036	0.11	847	0.02
Total	**50,611**	**1.23**	**55,878**	**1.35**	**5,267**	**0.13**

t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table A6: Cassava Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Eastern Thailand

Province	2005		2006		Increase or decrease	
	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
Chantaburi	40,034	1.17	41,351	1.21	1,316	0.04
Chachoengsao	42,702	1.21	43,747	1.24	1,045	0.03
Cholburi	45,190	1.27	45,535	1.27	345	0.01
Prachinburi	28,277	0.75	27,910	0.74	(368)	(0.01)
Rayong	34,994	1.10	36,544	1.15	1,550	0.05
Srakaew	62,288	1.67	62,890	1.68	602	0.02
Total	**253,485**	**7.17**	**257,976**	**7.30**	**4,491**	**0.14**

( ) = negative number, t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table A7: Cassava Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Northern Thailand

Province	2005		2006		Increase or decrease	
	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
Chiangrai	1,463	0.04	1,469	0.04	5	0
Kampangpet	72,923	1.81	74,444	1.84	1,522	0.04
Nakhon Sawan	32,181	0.71	32,833	0.73	652	0.02
Petchaboon	1,972	0.04	2,386	0.05	414	0.01
Pitsanuloke	24,183	0.28	25,563	0.29	1,380	0.02
Prae	171	0	192	0	21	0
Tak	813	0.02	803	0.02	(10)	0
Utai Thani	22,363	0.55	24,348	0.60	1,985	0.05
Uttraradit	3,813	0.09	4,407	0.11	594	0.01
Total	**159,881**	**3.54**	**166,445**	**3.68**	**6,564**	**0.15**

( ) = negative number, t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table A8: Cassava Planted Area, Interpreted from Landsat Images for 2005–2006, and Production Estimated from the Crop Simulation Model: Northeast Thailand

Province	2005		2006		Increase or decrease	
	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)	Area (hectares)	Production (million t)
Amnatcharoen	4,594	0.11	5,092	0.12	499	0.01
Burirum	35,458	0.96	40,899	1.11	5,441	0.15
Chaiyaphum	42,180	0.86	50,687	1.03	8,506	0.17
Kalasin	41,455	1.01	43,621	1.07	2,166	0.06
Khon Kaen	34,024	0.88	37,566	0.98	3,542	0.10
Loei	61,389	1.42	32,698	0.76	(28,691)	(0.66)
Mahasarakham	16,015	0.29	17,997	0.33	1,982	0.04
Mukdahan	22,972	0.57	24,099	0.60	1,127	0.03
Nakhon Panom	1,647	0.03	1,977	0.03	330	0.01
Nakhon Rachasima	227,896	5.52	243,780	5.92	15,884	0.40
Nongbua Lumphu	3,829	0.10	5,123	0.13	1,294	0.03
Nongkhai	9,084	0.32	9,483	0.33	398	0.01
Roi Et	13,182	0.29	13,790	0.31	608	0.01
Sakon Nakhon	12,686	0.27	13,702	0.29	1,016	0.02
Srisaket	10,402	0.30	11,254	0.32	852	0.02
Surin	6,135	0.18	6,509	0.19	374	0.01
Ubonrachathani	12,707	0.32	16,179	0.42	3,472	0.09
Udon Thani	18,093	0.48	23,080	0.61	4,987	0.13
Yasothon	8,439	0.23	9,021	0.24	582	0.02
Total	**582,187**	**14.118**	**606,554**	**14.78**	**24,367**	**0.66**

( ) = negative number, t = ton.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

Table A9: Oil Palm Planted Area, Interpreted from Landsat Image 2006, and Production Estimated from the Crop Model: Whole Kingdom

	Planted area (ha) with yields (tons/ha/year) of:			
Region	**<12.5**	**12.5–25.0**	**>25.0**	**Total**
Chumporn	22,695	33,347	2,090	58,132
Krabi	45,872	38,531	59,846	144,249
Nakon Srithamrat	996	177	9	1,182
Naratiwat	55	510	—	565
Pang-nga	5,451	2,522	1,759	9,732
Pattalung	26	—	—	26
Ranong	1,697	—	—	1,697
Satun	10,146	4,177	10,719	25,042
Songkhla	583	3,652	—	4,235
Surat Thani	34,250	27,074	3,539	64,863
Trang	3,204	3,097	4,108	10,409
Yala	7	—	—	7
Total in south	**124,981**	**113,087**	**82,072**	**320,139**
Cholburi	425	815	—	1,239
Rayong	582	—	—	582
Trad	12	55	—	67
Total in east	**1,020**	**869**	**—**	**1,889**
Overall total	**126,000**	**113,956**	**82,072**	**322,028**

— = no planted area with yield as specified, < = less than, > = more than, ha = hectare.

Note: The figures may not add up to totals because of rounding.

Source: Department of Agriculture.

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This report contains a detailed assessment of the status and potential for the development of biofuels in Thailand and presents a country strategy for biofuels development consistent with the Greater Mekong Subregion Regional Strategic Framework for Biofuel Development. The findings of the report were endorsed at the Fifth Meeting of the Greater Mekong Subregion Working Group on Agriculture on 22-24 September 2008 in Vientiane, the Lao People's Democratic Republic.

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