CHAPTER 6

ECONOMIC COMPETITIVENESS

In order to realize the biofuel targets outlined in Chapter 2, biofuel production in Thailand must present an economically competitive supplement and/or alternative to fossil fuels. Due to biofuels slight deficit in terms of energy content when compared to fossil fuels, it is generally desirable that biofuels are able to be produced and delivered to consumers at a cost less than the retail price of fossil transport fuels.

But economic competitiveness is not measured solely at the pump. Incentives in the form of financial profit are necessary at every stage of the biofuel production chain from the farm gate to fuel retailers. This is ultimately the only way to ensure that biofuel feedstock and biofuels are produced in the volumes required to meet the Thai Government's biofuel targets.

Importantly, if biofuels production is economically competitive, there is a greater chance that the resources employed in the production process are being utilized efficiently. As noted in previous chapters, the output of Thailand's biofuel industry is growing. This would seem to indicate that biofuels production in Thailand is already economically competitive and that there is scope to increase output further.

The main objective of this chapter is to examine the economic competitiveness of the Thai biofuels industry in more detail.

6.1 THE METHODOLOGY

The analysis covers biofuels produced from each key biofuel crop. The economic competitiveness of each fuel type is assessed with two main criteria: the final production cost per unit of biofuel and the internal rate of return.

To estimate final production costs a multi-stage process was employed. Firstly, a field survey was conducted to assess feedstock input costs targeting randomly selected farmers in selected provinces. The field survey took into account the farmer's economic situation and posed detailed questions about different cost components and necessary inputs. Farm level field surveys were only conducted for cassava production. Farm level data for sugar cane and oil palm was sourced from research already completed by the implementing partner organization.

Field surveys were also conducted canvassing different production facilities in order to develop scenarios to assess the viability of different production configurations. Some theoretical scenarios were also developed to provide points for comparison.

A spreadsheet model was then developed and populated using the data collected during the field surveys and various standard input and default values (prices, financial parameters, etc.). Final production costs were calculated for each specific production configuration scenario by dividing the difference between annual costs and revenues by the total production volume. All the results are expressed in Thai bath (THB), the local currency unit, and in US dollars ($). In the conversion it was used the 2009 exchange rate (35.6 THB for one dollar).

The scenario specific unit production cost was then compared with the reference retail prices for fossil fuels and generic reference prices for ethanol and biodiesel. The reference prices used for this analysis were collected in September 2009 and are presented in Table 6.1.

TABLE 6.1

Reference retail prices for transport fuels in September 2009

Fuel category	Type of fuel	THB/L	$/L
Ethanol	Reference Case	19.30	0.60
Fossil gasoline[1]	Gasohol 95 - E10	31.04	0.97
	Gasohol 95 - E20	28.74	0.90
	Gasohol 95 - E85	22.72	0.71
	Gasohol 91 - E10	30.24	0.95
	ULG 95 RON	40.24	1.26
	UGR 91 RON	34.64	1.08
Biodiesel	Reference case	27.90	0.87
Fossil diesel	Low-sulfur diesel[2]	26.79	0.84
	Diesel - B5[3]	25.39	0.79

[1] Gasohol is a motor fuel blend of petrol and ethanol. Gasohol 95 is the name of the blend currently available in Thailand, where 95 is the octane rating. If it is E10, this fuel is a 90 percent petrol and ten percent ethanol (E20 would have 20 percent ethanol and so on). Gasohol 91 is the name of the blend where 95 is the octane rating. ULG 95 RON is the unleaded premium gasoline with 95 Research Octane Number (RON); URG 91 RON is the unleaded regular gasoline with 91 Research Octane Number. RON measures the antiknock performance of a motor fuel.

[2] Diesel with sulfur level equal to 0.035 percent.

[3] Diesel blended with five percent of biodiesel.

Source: JGSEE.

The internal rate of return (IRR) is used as the second indicator of economic competitiveness for each production configuration scenario. The IRR was estimated based on established periodical cash flows and by calculating the net present value (NPV) for the investment. The investment period used for this calculation was 20 years.

In this chapter, investments are accounted for using the annuity method, in which the total investment over the depreciation period and the interest rate are expressed as average yearly cost. These are used as well in the spreadsheet and cash flow analysis, which calculates the NPV and the IRR.

6.2 RESULTS

6.2.1 Competitiveness of cassava-based ethanol

Table 6.2 presents the average national values regarding the cost structure of cassava farming in Thailand.

Over the period from 1997 to 2008 the total cost of producing cassava more than doubled from almost 9 900 THB/ha (278 $/ha) to more than 22 900 THB/ha (643 $/ha). Variable costs were the largest component of the cost structure accounting for an average of 86 percent of total costs over the whole period. The growth in variable costs was attributed to increases in fertilizer costs. This was verified by the field surveys and discussed in more detail below.

While Table 6.2 presents total average values for Thailand, it should be noted that the situation may be very different for individual producers depending on the fertility of the soil and the inputs used. It is likely that there are large regional differences due to rainfall, different water situations and soil quality, as indicated by the results of the field surveys.

The range of production costs recovered from the field surveys is slightly greater than the national averages reported in Table 6.2 with survey respondents estimating total production costs of between 18 750 THB/ha (527 $/ha) and 29 375 THB/ha (825 $/ha). However, reported revenues were also much higher than the national average. This was attributed to higher average yields in the surveyed areas and higher reported prices for cassava root output.

TABLE 6.2

Development of cost structure for cassava from 1997 to 2008

Details	Unit	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Variable cost	THB/ha	8 088	9 594	11 200	10 894	12 350	12 019	12 206	12 306	13 731	15 694	15 250	19 694
Fixed cost	THB/ha	1 756	1 756	1 756	1 756	1 756	1 756	2 163	2 094	2 094	2 094	2 094	3 244
Total cost	THB/ha	9 844	11 350	12 956	12 650	14 106	13 775	14 369	14 400	15 825	17 788	17 344	22 938
Yield	kg/ha	14 700	14 900	15 500	16 900	17 500	17 900	17 900	20 300	17 200	21 100	22 300	21 300
Profit*	THB/ha	4 856	3 575	2 538	4 206	3 425	4 150	3 575	5 875	1 356	3 306	4 919	-1 681

* Based on one THB/kg for cassava price.

Source: OAE, updated March 2009.

For long periods the average price for cassava root was stagnant at around one THB/kg. During 2007 and especially in 2008, the price for cassava root jumped reaching a maximum of 2.3 THB/kg. Since this time cassava root prices have remained well above the one THB/kg reference price. This information was verified in the field surveys. Respondents reported an average price of 1.65 THB/kg for raw cassava root, which is greater than the long-standing average price of one THB/kg and explains the higher reported revenues.

In general, cassava cultivation provides a low income to producers. Since profit margins are so narrow, producers try to minimize their risk and keep their costs down by growing cassava on less fertile lands with minimal inputs. Given Thailand's climate and good agronomic conditions, it should be possible to increase yields and raise farm incomes. This was confirmed by the findings of the field surveys which indicate that yield improvement, through sustainable agricultural practices and appropriate use of fertilizer, whether chemical or organic, could increase net profits.

For example, in Ratchaburi province there is little use of fertilizer and, as a result, low yields and only limited net profits of 8 437 THB/ha (237 $/ha). It is possible to increase profits substantially with moderate growth in the level of inputs to levels similar with those employed in Kamphangphet province. Of the provinces included in the field survey, Rayong province showed most potential to benefit from moderate growth in fertilizer use.

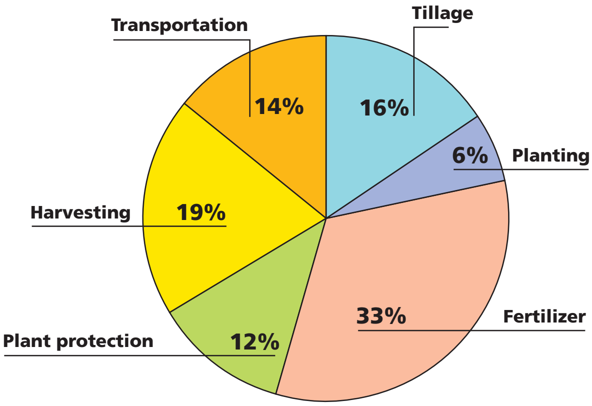
Figure 6.1 presents the average cost structure of farms assessed for the field survey. Here it can be seen that roughly 33 percent of total costs are related to purchasing, transporting and distributing fertilizer, whether mineral/chemical fertilizer or organic. The most common form of organic fertilizer used by respondents was chicken dung, which is mainly transported in rented vehicles and manually spread on the fields. The next largest cost component is preparing the land including tillage and planting the cassava stem.

Table A6.1 in Appendix summarizes the individual results from the field surveys in five provinces. It provides details of the individual expenses of each production step as a minimum, a maximum and an average value for the different locations and farmers visited and reveals large differences.

The three production configurations that were used to assess the economic competitiveness of cassava-based ethanol in Thailand are presented in Table 6.3. Detailed information regarding each configuration was collected during field visits conducted in mid-2009.

FIGURE 6.1

Average cost structure of cassava plantation



Source: based on the field survey carried out by JGSEE.

TABLE 6.3

Characteristics of cassava-based ethanol configurations

Production scenario	Description
Low efficiency fossil (LEF)	■ 36.5 million litre capacity powered by coal and electricity grid ■ Ethanol produced from fresh cassava root
Medium efficiency fossil with waste water management (MEF)	■ 73 million litre capacity powered by coal and electricity grid ■ Biogas plant established to generate additional energy from waste water flows ■ Ethanol produced from cassava chips
Renewable energy (RE)	■ 73 million litre capacity powered by renewable feed electricity plant attached to co-located sugar mill ■ Biogas plant established to generate additional energy from waste water flows ■ Ethanol produced from cassava chips with capacity to switch to molasses

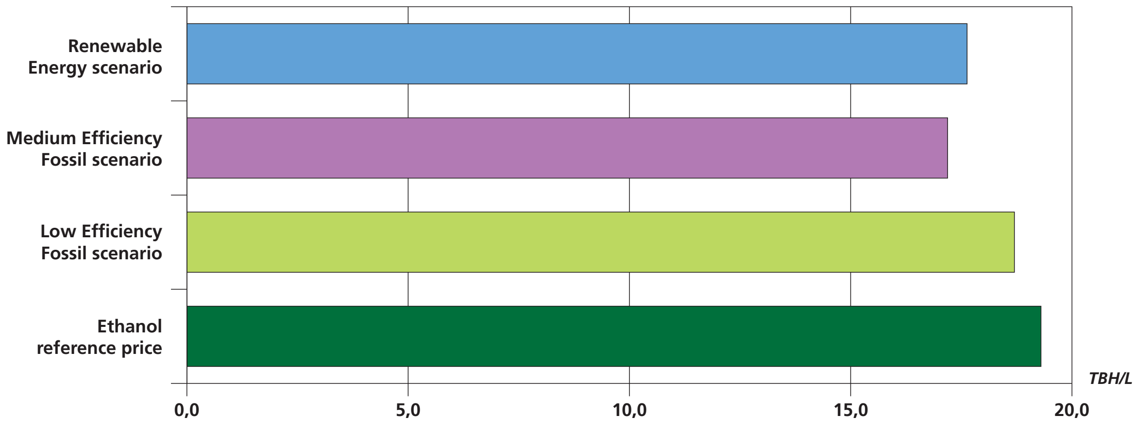
Source: JGSEE.

From Figure 6.2 and Table 6.4 it can be observed that when using the final total production cost criteria, cassava ethanol is found to be competitive under each scenario when compared to the reference retail prices in Table 6.1. The final total cost of each production configuration is below the ethanol reference price of 19.3 THB/L and well below the reference fossil gasoline price. In making these calculations it is assumed that the price of cassava root feedstock is 1.8 THB/L and the price of cassava chip feedstock is four THB/kg. While greater than the long-standing one THB/kg reference price for cassava root, the reference price is less than the peak cassava root prices observed in 2008.

As can be seen in Table 6.4, using the IRR as the second criteria of economic competitiveness yields a similar conclusion. Cassava-based ethanol production is found to deliver rates of return above ten percent for the project implementers. The calculated after tax NPV of each scenario over a 20 year investment period

FIGURE 6.2

Comparison of cassava-based ethanol production costs



Source: JGSEE.

TABLE 6.4

Production cost and IRR for cassava-based ethanol scenarios

Production scenario	Production cost THB/L	IRR w/o tax %
Low Efficiency Fossil	18.70	12.36
Medium Efficiency Fossil	17.19	18.75
Renewable Energy	17.63	23.31

Source: JGSEE.

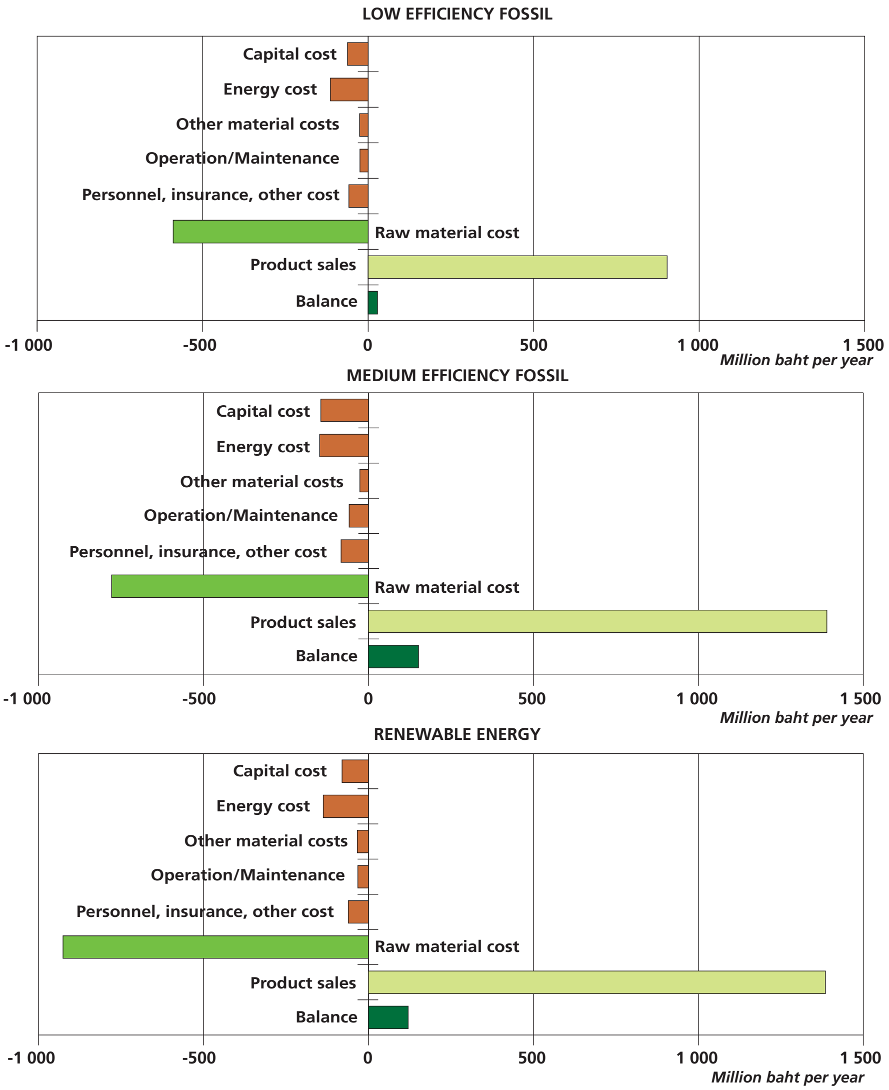
is also positive and ranges from around 279 million THB (7.9 million dollars) for the LEF scenario to 1.5 billion THB (42.2 million dollars) for the MEF scenario.

As can be seen in Figure 6.3, the cost and benefit summaries for each production scenario show that raw material costs are the largest cost component of cassava ethanol production.

Small changes in the product sales price or the price of raw materials could have a big effect on the economic competitiveness of cassava ethanol. To illustrate the effect of changes in output and input prices on the economic competitiveness of cassava ethanol production three scenarios of sensitivity analysis were undertaken. The results are shown in Table 6.5.

FIGURE 6.3

Cost and benefit summary for cassava-based ethanol scenarios



Source: JGSEE.

TABLE 6.5

Results of sensitivity analysis

Production scenario	Production cost	IRR w/o tax	Production cost growth rate	IRR Variation
	THB/L	%	%	%
Sensitivity Analysis Scenario 1: 20 percent increase in feedstock prices				
Low Efficiency Fossil	21.22	negative	13.5	negative
Medium Efficiency Fossil	19.35	6.66	12.6	-12.09
Renewable Energy	20.20	negative	14.6	negative
Sensitivity Analysis Scenario 2: one THB reduction in ethanol sales price				
Low Efficiency Fossil	18.70	2.86	0.0	-9.50
Medium Efficiency Fossil	17.19	13.50	0.0	-5.25
Renewable Energy	17.63	14.08	0.0	-9.23
Sensitivity Analysis Scenario 3: 30 percent decrease in the cost of energy				
Low Efficiency Fossil	18.11	17.08	-3.1	4.72
Medium Efficiency Fossil	16.81	20.68	-2.2	1.93
Renewable Energy	17.13	27.65	-2.8	4.34

Source: JGSE.

As previously noted, the main costs are raw materials or feedstock. The first scenario estimates the impact of a 20 percent increase in feedstock prices. As can be observed in Table 6.5, the production cost increases as would be expected. However, the largest impact is on the IRR. The increase in feedstock prices results in both the RE and LEF scenarios returning negative IRR. While the MEF returns a positive IRR, it is considerably less than the base scenario.

This confirmed feedback from producers collected during the field visits that ethanol refineries would likely not be financially viable under high cassava prices such as those experienced in 2008. In fact, a number of planned refineries did not begin operation and planned investment was postponed at this time due to these high prices together with the still limited market in Thailand for ethanol. This would seem to indicate that the industry is highly sensitive to changes in feedstock cost.

The second sensitivity analysis scenario assumes a one THB/L reduction in the reference market price for ethanol to 18.30 THB/L. Under this scenario the LEF scenario is unviable on a cost comparison basis. The reduction in the sales price also results in a significant reduction in the IRR of each production configuration scenario.

The final sensitivity analysis scenario assumes a 30 percent reduction in energy expenses due to the partial substitution of fossil fuels by sourcing energy from co-located operations and/or the use of biogas technology from wastewater treatment. Under each production configuration costs are reduced and the IRR improves. The field surveys indicate that changing the energy configuration of existing facilities would be viable at a number of sites in Thailand. This finding also implies that future cassava ethanol production facilities should be encouraged to investigate these energy conservation options.

6.2.2 Competitiveness of sugar-based ethanol

The four production configurations that were used to assess the economic competitiveness of sugar-based ethanol in Thailand are presented in Table 6.6. As noted in Section 6.1, for the purpose of this study farm level data for sugar cane was drawn from previous research undertaken by the implementing organization. In calculating the final cost of production per unit of ethanol it is assumed that the price of molasses feedstock is three THB/kg and the price of raw and condensed sugar juice is 1.4 THB/kg and four THB/kg respectively.

As illustrated in Table 6.7, the results indicate that the final per unit production costs for sugar-based ethanol are competitive under each production scenario. Production costs are below the ethanol reference price of 19.3 TBH/L for each configuration and well below the fossil gasoline reference price (Table 6.1). The lowest production costs are associated with molasses-based ethanol using an on-site refinery, which reduces transportation costs and allows

TABLE 6.6

Characteristics of sugar-based ethanol configurations

Production scenario	Description
Sugar – On-site	■ 182.5 million litre capacity powered by renewable energy (bagasse) plant attached to sugar mill ■ Ethanol produced from sugar juice ■ Theoretical scenario – no actual example in Thailand
Molasses – Rice Husk	■ 73 million litre capacity powered by renewable energy (rice husk cogeneration plant) ■ Molasses transported to off-site refinery for processing
Molasses – Stand Alone	■ 73 million litre capacity powered by renewable energy (bagasse) plant attached to sugar mill ■ Additional feedstock is sourced from surrounding suppliers
Molasses – On-site	■ 73 million litre capacity powered by renewable energy (bagasse) plant attached to sugar mill ■ Energy and feedstock are made available at internal prices

Source: JGSEE.

energy supplies to be sourced from a co-located sugar mill. Most existing ethanol facilities in Thailand follow this production configuration, which suggests that the industry is already quite competitive. The final cost of production for each sugar ethanol production configuration is also equal to or less than the cassava ethanol scenarios.

When using the IRR as the second criteria of economic competitiveness, sugar ethanol production under existing practices is found to deliver rates of return well above those observed for cassava, averaging over 20 percent. The calculated after tax NPV of each scenario using a 20 year investment period is also positive and ranges from around 1.5 billion THB (42.8 million dollars) for the Molasses Stand Alone scenario to 3.5 billion THB (99.4 million dollars) for the Sugar scenario. However, it should be noted that there is currently very little ethanol production under the Sugar scenario in Thailand.

TABLE 6.7

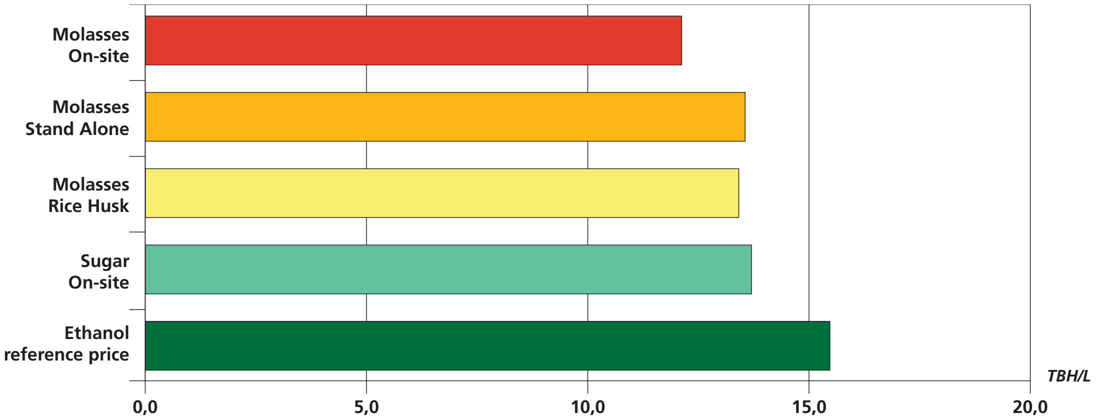
Production cost and IRR for sugar-based ethanol scenarios

Production scenario	Production cost	IRR w/o tax
	THB/L	%
Sugar – On-site	17.09	33.56
Molasses – Rice Husk	16.73	29.80
Molasses – Stand Alone	16.91	28.34
Molasses – On-site	15.12	42.76

Source: JGSEE.

FIGURE 6.4

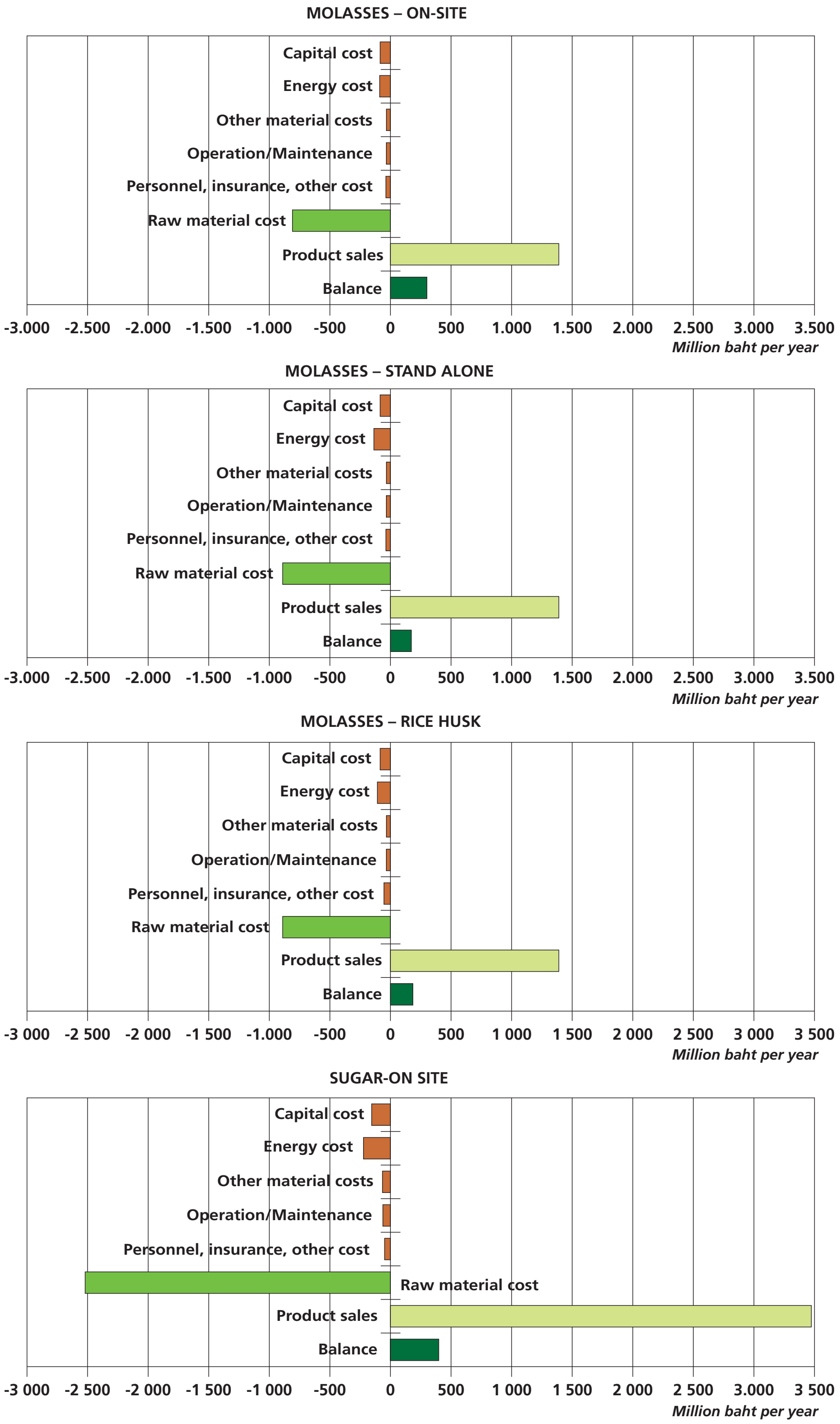
Comparison of sugar-based ethanol production costs



Source: JGSEE.

FIGURE 6.5

Cost and benefit summary for sugar-based ethanol scenarios



MOLASSES – ON-SITE

MOLASSES – STAND ALONE

MOLASSES – RICE HUSK

SUGAR-ON SITE

Like cassava-based ethanol, feedstock costs are the largest cost component of each sugar-based ethanol production configuration. The next largest components are energy and capital costs.

While no sensitivity analysis was conducted for sugar ethanol, based on this cost structure analysis it could be assumed that significant changes in the price of feedstock would have considerable impact on the economic competitiveness of sugar-based ethanol production in Thailand.

6.2.3 Competitiveness of biodiesel

The four production configurations that were used to assess the economic competitiveness of biodiesel in Thailand are presented in Table 6.8. As noted in Section 6.1, for the purpose of this study farm level data for the oil palm sector was drawn from previous research undertaken by the implementing organization. In calculating the final cost of production per unit of biodiesel it is assumed that the price of crude palm oil (CPO) and refined palm oil, 25 THB/kg and 30 THB/kg respectively and the price of both stearine and waste cooking oil feedstocks, is ten THB/kg.

TABLE 6.8

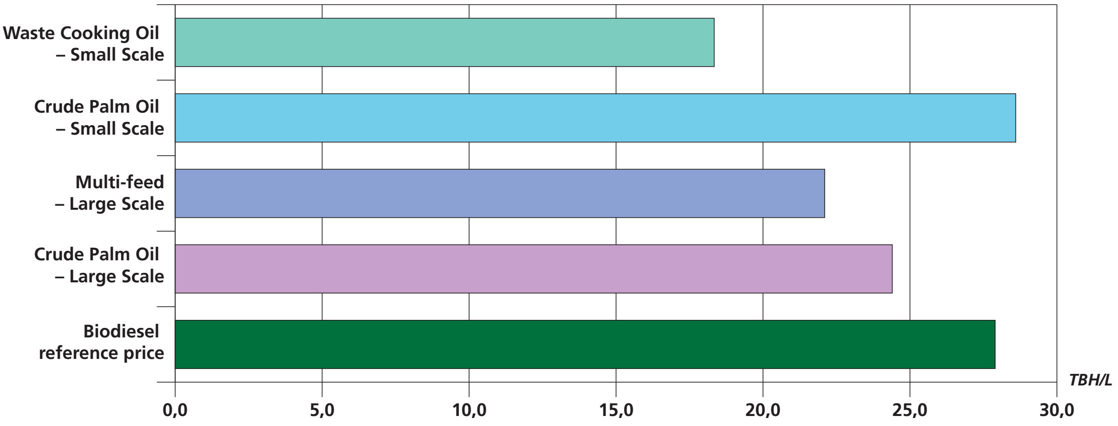
Characteristics of biodiesel configurations

Production scenario	Description
CPO – Large Scale	■ 146 million litre capacity powered by grid electricity and/or coal ■ CPO is produced in location proximate to oil palm plantation ■ CPO transported to off-site biodiesel refinery
Multi-Feed – Large Scale	■ Feedstock includes CPO, refined palm oil, stearine and waste cooking oil
CPO – Small Scale	■ 365 thousand litre capacity powered by grid electricity and/or coal ■ Batch operation
Waste Cooking Oil – Small Scale	■ 365 thousand litre capacity powered by grid electricity and/or coal

Production costs for biodiesel are competitive under most feedstock scenarios (Figure 6.6 and Table 6.9). Generally, production costs are below the biodiesel reference price of 27.9 THB/L for each configuration and below the fossil diesel reference price of 26.8 THB/L. Interestingly, the small-scale configuration using CPO as feedstock is found to be economically unviable because the conversion process is less efficient and requires more inputs per unit of output.

FIGURE 6.6

Comparison of biodiesel production costs



Source: JGSEE.

The current Thai biodiesel industry employs the large-scale, CPO configuration implying that biodiesel produced in Thailand is a competitive alternative source of transport fuel.

The calculated IRR for each production configuration other than the small-scale, crude palm oil configuration are considerably large, well above those for either cassava or sugar ethanol. The IRR for the small-scale crude palm oil scenario is negative and supports the finding that this production configuration is economically unviable in Thailand. The calculated after tax NPV of each scenario using a 20 year investment period is positive for the remaining three scenarios and ranges from around 30.7 million THB (863 000 dollars) for the Waste Cooking Oil scenario to 7.4 billion THB (208 million dollars) for the Biodiesel Multi-feed scenario.

As in the case of cassava and sugar ethanol, feedstock costs largely determine whether or not biodiesel from palm oil is economically competitive (Figure 6.7). Strategies that reduce the cost of feedstock costs will dramatically improve the economic competitiveness of biodiesel produced in Thailand.

TABLE 6.9

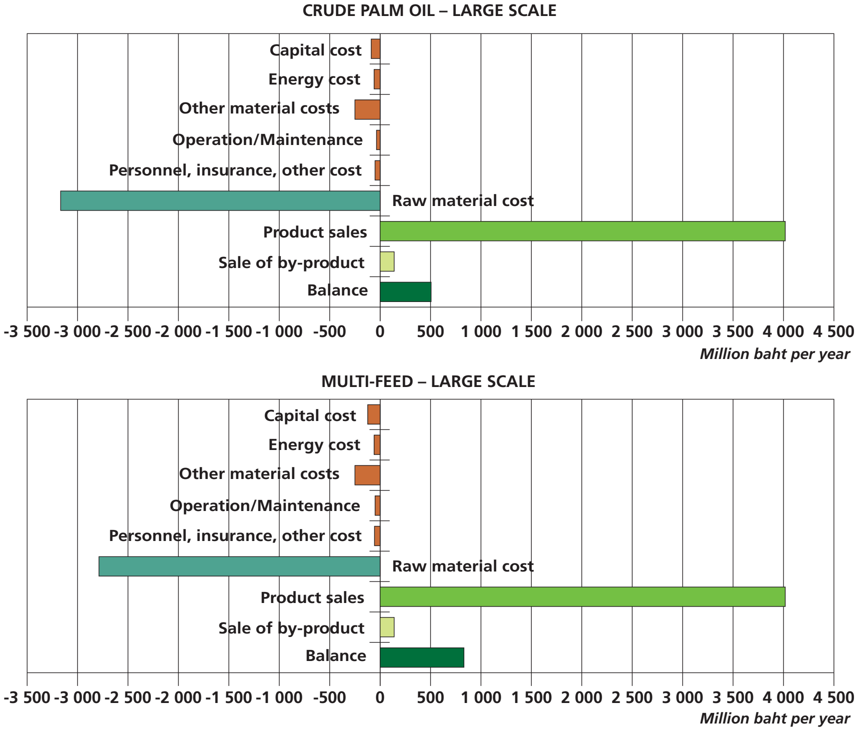
Production cost and IRR for biodiesel scenarios

Production scenario	Production cost	IRR w/o tax
	THB/L	%
CPO – Large Scale	24.4	63.63
Multi-feed – Large Scale	22.1	73.32
CPO – Small Scale	28.6	N/A
Waste Cooking Oil – Small Scale	18.34	476.30

Source: JGSEE.

FIGURE 6.7

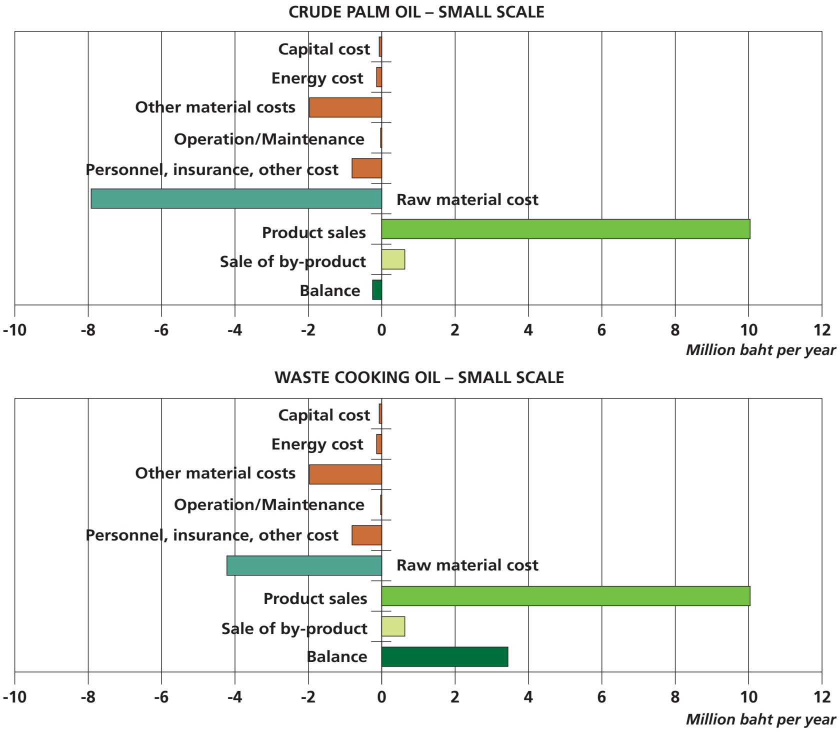
Cost and benefit summary for large scale biodiesel scenarios



Source: JGSEE.

FIGURE 6.8

Cost and benefit summary for small scale biodiesel scenarios



Source: JGSEE.

6.3 CONCLUSIONS

- *Biofuels produced in Thailand are generally competitive with fossil fuels.* Generally, each production configuration scenario analyzed had lower final per unit production costs than both the prevailing fossil fuel equivalent and the biofuel reference price. The only exception was the small-scale, crude palm oil biodiesel scenario which displayed a number of inefficiencies associated with insufficient scale. Similarly, the return on investment under the various scenarios was strong, indicating there should be sufficient incentive for the private sector to expand the biofuel industry in a manner that would support the realization of the Thai Government's biofuel targets.
- *Feedstock costs are the deciding factor of the economic competitiveness of biofuel production in Thailand.* Small changes in these costs can have a large effect on the financial viability. The cost of feedstock was the largest cost component of each scenario analyzed. The sensitivity analysis conducted for the cassava production configurations indicates that changes in the price of feedstock can have dramatic effects on the final production cost per unit of output and overall financial viability. There is evidence that recent spikes in the price of cassava have already delayed further development of the cassava ethanol sector in Thailand. Managing potential fluctuations in feedstock prices will be crucial to ensure the future viability of the biofuels industry in Thailand.
- *Improving the yields of key biofuel feedstock crops will provide an avenue to reduce feedstock costs and boost economic competitiveness.* The farm site field research that was undertaken for the cassava analysis

indicates that one possible way to reduce feedstock costs would be to improve the yields of domestic biofuel feedstock producers. The field research discovered potential to improve cassava yields cost effectively through small increases in intensification. This finding is also confirmed by the analysis in Chapter 5. Greater feedstock production per area of land would deliver the twin benefits of improving returns for farmers through higher sales volumes and keeping feedstock costs low by maintaining a consistent supply of locally available feedstock.

6.4 REFERENCES

Arirachakaran S. 2009. *Thai Ethanol Industry: Sustainability Today and Tomorrow*, Bangkok Biofuels 2009, Bangkok.

Giersdorf J. 2009. *Second Generation Biofuels Risks and Opportunities for Developing Countries*, Thailand, DBFZ, Leipzig.

Klanarong S. 2007. *Processing of cassava waste for biomass energy production*, Biotec, Bangkok.

LDD. 2006. *GIS data for Thailand*, Land Development Department, Bangkok.

MoE. 2009. *Alternative Energy Promotion Measures*, Ministry of Energy, Bangkok. Available at www.dede.go.th/dede/fileadmin/upload/pictures_eng/pdffile/AE_Promotion_Measures.pdf.

NSO. 2008. *The 2003 agricultural census*, National Statistical Office, Bangkok.

OAE. 2009. *Cassava production in Thailand*, translated from Thai language, Bangkok.

Pattanapanchai A. 2008. *Investment incentives and opportunities of biofuel and bioplastics business in Thailand*, EcoInnovAsia 2008, Bangkok.

Siemers W. 2009. *Development of tools to estimate alternative strategies and options in using biomass for energy*, Thailand Research Fund, Bangkok.

Sriyunyongwat V. 2009. *ASEAN Development and direction for 2nd generation technologies*, Bangkok Biofuels 2009, Bangkok.

Data were collected from the following websites:
DEDE website: www.dede.go.th.
EPPO website: www.eppo.go.th.
OAE website: www.oae.go.th.
Office of the Cane and Sugar Board (OCSB) website: www.ocsb.go.th.

6.5 APPENDIX

TABLE A6.1

Summary of cassava production cost and revenues from field survey

		Buriram Nakornratchasima			Rayong			Ratchaburi			Chonburi			Kampangphet		
	Unit: THB/ha	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**
Tillage	Own tractor	-	-	-	625	1 875	1 250	-	569	288	438	488	463	-	900	450
	No tractor	2 875	4 375	3 625	2 750	3 750	3 250	-	4 375	2 188	4 125	4 250	4 188	2 875	3 438	3 156
Planting	Manual work	-	1 875	1 875	1 125	1 563	1 344	938	1 563	1 250	938	1 625	1 281	1 438	2 188	1 813
Fertilizer	Organic fertilizer (without vehicle)	3 125	8 438	5 781	-	9 375	4 688	-	2 219	1 113	-	6 000	3 000	1 500	2 625	2 063
	Organic fertilizer (with vehicle)	-	-	-	-	750	375	-	2 469	1 238	-	4 019	2 013	-	-	-
	Chemical fertilizer	3 125	8 438	5 781	5 000	8 125	6 563	-	-	-	4 219	6 563	5 394	-	3 188	1 594
Plant protection	Material paraquat	1 063	2 188	1 625	563	656	613	-	1 875	938	-	813	406	375	513	444
	Labour	1 125	1 563	1 344	500	1 125	813	-	1 250	625	500	750	625	938	1 063	1 000
	Labour without material	1 250	1 875	1 563	1 250	1 875	1 563	-	938	469	938	1 875	1 406	1 000	1 250	1 125
Harvesting	Labour (harvest)	3 750	4 500	4 125	4 500	5 000	4 750	5 000	7 500	6 250	-	-	-	-	-	-
	Tractor (harvest)	-	-	-	-	-	-	-	2 113	1 056	-	1 563	781	6 625	7 500	7 063
Transport	With own truck	-	-	-	-	500	250	-	1 563	781	-	-	-	-	-	-
	Without own truck	1 250	5 000	3 125	3 000	5 000	4 000	3 750	8 750	6 250	-	5 375	2 688	-	-	-
Total production cost (THB/ha)		17,563	38 252	28 844	19 313	39 594	29 459	9 688	35 184	22 446	11 158	33 321	22 245	14 751	22 665	18 708
	Yield (tons/ha)	25.0	40.6	31.3	43.8	56.3	50.0	15.6	21.9	18.8	25.0	28.1	28.1	31.3	46.9	37.5
	Price (THB/ton)	1 500	1 800	1 650	1 500	1 800	1 650	1 500	1 800	1 650	1 500	1 800	1 650	1 500	1 800	1 650
Total revenue (THB/ha)		37 500	73 125	51 563	65 625	101 250	82 500	23 438	39 375	30 938	37 500	50 625	46 406	46 875	84 375	61 875
Total profit (THB/ha)		19 937	34 873	22 719	46 312	61 656	53 041	13 750	4 191	8 492	26 342	17 304	24 161	32 124	61 710	43 167

CHAPTER 7

CLIMATE CHANGE MITIGATION

In the previous chapter we learned that based on the BEFS analysis, biofuels produced in Thailand are economically competitive. But while economically viable, Thailand's biofuel targets may have external costs that could feasibly reduce the full economic benefit of producing and using these fuels. As liquid biofuels development has been promoted as a means to reduce greenhouse gas emissions and improve environmental outcomes in the transport sector, it is important to investigate the impact of these fuels on the climate to confirm their value as a policy tool.

For example, if the production of biofuels in Thailand resulted in the emission of greenhouse gases in excess of those associated with fossil fuels then serious questions would need to be asked regarding the sustainability of Thailand's biofuels targets. In this instance, policy makers may feasibly be able to identify other low emissions solutions to satisfy their environmental objectives in the transport sector. Similarly, if the energy consumed in producing biofuels in Thailand exceeded that used in the production of fossil fuels, from a policy perspective the Thai Government might be able to identify more energy efficient solutions to meet its energy policy objectives.

The main objective of this Chapter is to look at the impact of biofuels produced in Thailand in terms of greenhouse gas emissions and energy balance. To complement and build on the analysis presented in the previous chapter, a full life cycle analysis (LCA) has been developed for each of the biofuel production configurations employed in the economic analysis.

7.1 THE METHODOLOGY

The analysis employed in this chapter uses a LCA to evaluate the final GHG emissions and energy consumed from biofuels production in Thailand. The LCA is a tool for the systematic evaluation of potential environmental impacts associated with a product, process or activity, from production of the raw materials through to its final disposal. In this case, the LCA focuses on the emission of greenhouse gases and energy required at every stage of the biofuel production chain from the farm to refinery gate. The farm level analysis for cassava also considers the implications of land-use and crop changes and their impact on the final GHG balance of cassava ethanol.

For the purpose of BEFS the LCA of biofuels produced in Thailand was developed using the Global Emission Model for Integrated Systems (GEMIS) program. The GEMIS software was produced by the Oeko-Institut and is widely used internationally to quantify a range of environmental phenomenon associated with various agricultural and industrial processes including GHG emissions, energy balance, resource and material demands and other environmental impacts. Final results are presented as a value per unit of energy - in this case per one megajoule (MJ) of the relevant biofuel. The measures calculated for this study are displayed in Table 7.1. The results also yield information on energy requirements, which as noted above can be used as an additional parameter of analysis. One advantage of employing the GEMIS software for this analysis is that due to its wide use and open availability, it is already populated with range of relevant data.

TABLE 7.1

Measures of GHG emissions and energy requirements

Signifier	Description
CO_{2eq}	Total GHG emissions are expressed as carbon dioxide equivalent using the different relevant global warming. The unit is grams of CO_{2eq} per MJ (gCO_{2eq}/MJ) and tonnes of CO_{2eq} per hectares (tonsCO_{2eq}/ha).
CO_2, CH_4, N_2O	Carbon dioxide (g/MJ), nitrous oxide (mg/MJ) and methane (mg/MJ) are the individual key values of the main greenhouse gases.
SO_{2eq}	Sulfur dioxide equivalent (mg/MJ) shows the emission levels of sulfur dioxide, carbon monoxide, nitric oxide and other emittants.
TOPP	Tropospheric ozone precursor potential (mg/MJ) is caused by different tracer gases like nitric oxide, ammonia and carbon monoxide.
Non RE	The non renewable energy requirement – i.e. the fossil energy portion expressed in MJ/MJ.
Renewable	The renewable energy requirement expressed in MJ/MJ.

The implementation of the LCA methodology involves five main steps: 1) setting the system boundary for evaluation, 2) data gathering to establish data inventory, 3) in the case of cassava, defining and calculating emissions from the land-use change and crop to crop changes on agricultural production of biofuel crop, 4) calculation of the GHG balance for the overall biofuel production and 5) analysis on sustainability using the final values of GHG emissions and energy demand as criteria.

As noted above the LCA analysis was applied to each of the biofuel production configuration scenarios employed in Chapter 6. Some additional scenarios were also established to observe how slight changes in the production chain might affect the final GHG balance. For example, in the case of cassava scenarios were developed for low and high input agriculture and various land-use and crop changes, in the case of sugar hypothetical scenarios were developed for fossil powered refineries and in the case biodiesel additional scenarios were developed for large-scale waste cooking oil and stearine production facilities. For land use and crop changes associated with cassava production new values were constructed to feed into the GEMIS software consistent with the Intergovernmental Panel on Climate Change (IPCC) guidelines. A detailed methodology for the calculation of emissions associated with land-use and crop change can be found in IPCC, 2006.

Each scenario was also developed in accordance with the latest European Union (EU) definitions of biofuels, which allowed for meaningful comparison with the latest EU emission reductions standards. The EU sustainability criteria assess biofuels in terms of their net GHG savings when compared to the fossil alternatives. The Thailand specific values relating to the EU sustainability criteria have been calculated for the purpose of this work and are presented in Table 7.2.

TABLE 7.2

EU requirements for sustainable biofuels

Case/option	GHG emissions gCO_{2eq}/MJ
Thailand calculated 35 percent reduction with respect to the baseline	60.88
EU target for 35 percent reduction effective since 2009	54.47
EU target for 50 percent reduction in 2017	41.90
EU target for 60 percent reduction after 2017	33.52

Source: JGSEE.

According to EU sustainability laws and regulations only biofuels that fulfil certain requirements can qualify for import into the EU and be considered as renewable energy sources for EU quotas. The EU sustainability criteria for biofuels require a global 35 percent reduction in GHG emissions against the baseline scenario in order to meet its import requirements. Either the national fossil gasoline or diesel value may be used as the baseline measure. Otherwise the default value given by the EU may be applied. Both are used as point of comparison in this analysis.

Based on the value for Thai gasoline in this study, a 35 percent reduction would limit the allowable GHG emissions to 60.88 gCO_{2eq}/MJ. However, the effective default for the 35 percent reduction that applies in the EU is slightly lower at 54.47 gCO_{2eq}/MJ. The application of the 35 percent rule to the Thai gasoline supplies is slightly different to the EU value due to the application of slightly different system boundaries in this study. The reduction target of 35 percent is in effect until 2017. After that period, the criteria are more stringent as the GHG savings should reach 50 percent and possibly 60 percent after 2017.

7.2 RESULTS

7.2.1 GHG emissions of cassava-based ethanol

As with the economic analysis presented in Chapter 6, special attention was paid to developing the LCA for cassava ethanol. The reasons behind this were two-fold. Firstly, unlike sugar ethanol and palm oil biodiesel, cassava ethanol has received little attention from LCA experts operating in Thailand. As a result, very little existing data was available to populate the GEMIS model, which necessitated the development of original datasets for each stage of the production process. Secondly, as Thailand's biofuel targets anticipate that cassava ethanol will become a key component of future ethanol consumption further detailed investigation of this particular biofuel was considered appropriate and necessary. As much of Thailand's available land is already under cultivation particular effort was employed to better understand the possible effects of land-use and crop changes associated with an expansion of cassava at the expense of virgin land or existing agricultural crops.

7.2.1.1 GHG emissions in the agricultural production of cassava

The main elements of the agriculture production baseline are the use of fossil fuels for land preparation and transport and the use of mineral fertilizers and chemicals. Note that human labour is not included as an energy source or GHG input into the system.

Based on data retrieved from the field surveys three cassava production scenarios were developed: low, medium and high level of inputs (mainly a function of fertilizer and resulting yields). Table 7.3 presents the different parameters of these scenarios. While increased inputs of fertilizer would lead to higher yields, there are diminishing returns as more inputs are applied. Soil characteristics also play an important role in determining whether plantings respond to greater inputs.

TABLE 7.3

Average figures for cassava production

Factor	Unit	Low input	Medium input	High input
Yield	ton/ha MJ/ha	23 78 660	36 123 120	50 171 000
Nitrogen (N)	kg/ha	30	40	180
Phosphorus (P_2O_5)	kg/ha	20	40	60
Potassium (K_2O)	kg/ha	20	40	75
Chemicals	kg/ha	6	6	6
Diesel	L/ha	60	60	60

Source: JGSEE.

The calculated mean values from these scenarios are used to calculate the overall values for input into GEMIS (Table 7.3). To be suitable for use in GEMIS, these values need to be recalculated and specified as a value per MJ. The final results of the GEMIS calculation are shown in Table 7.4. It is worth noting that the value for renewable energy is specified as one MJ/MJ. This is because the energy value of the source material is considered to be already included in the final output. This means that exactly one MJ of biomass material is required to produce one MJ of cassava root output.

TABLE 7.4

Emissions and energy demand for cassava production

Agricultural production scenario	Emissions						Energy requirement	
	CO_{2eq}	CO_2	CH_4	N_2O	SO_{2eq}	TOPP	Non RE	Renewable
	g/MJ	g/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	MJ/MJ	MJ/MJ
Low input level	6.93	5.04	5.71	5.93	45.86	49.84	0.081	1.00
Medium input level	5.43	3.83	4.80	5.04	34.93	35.98	0.062	1.00
High input level	10.87	5.93	9.10	15.99	55.73	51.12	0.095	1.00

Source: JGSEE.

From Table 7.4 it can be observed that final CO_{2eq} emissions per unit of output increase from low to high level of inputs. This is due largely to the application of more mineral fertilizers in the high input scenario. In the case of medium scenario, small additional inputs result in increased yields and reduced emissions. This is because the increase in yield offsets the associated increase in GHG emissions. As a result, the final values for GHG emissions and energy requirements are lower than both the low and high level of inputs scenarios.

The values in Table 7.4 do not include the possible implications of land use change and crop change on the final GHG emission balance.

7.2.1.1 GHG emissions with land use and crop change in cassava production

To produce the agricultural baseline for cassava special consideration was given to assessing the impact of land-use and crop change on final GHG emissions. Land use change (LUC) involves the conversion of non-cultivated land or land classified as other than agricultural land (e.g. forest land). Crop change (CC) refers to changes that occur when annual crops are interchanged on the same land area.

As noted above, the full methodology used to calculate the emissions associated with LUC and CC is the one defined in the IPCC guidelines. Supporting data for the calculation of the LUC and CC values was collected during the field surveys conducted in June and July 2009. Based on the field survey and other available data the following possible categories of LUC and CC were identified as most relevant to cassava production in Thailand:

- CC from maize to cassava;
- CC from sugar cane to cassava;
- CC from rice to cassava;
- LUC set aside land/pasture to cassava;
- LUC unused/partially degraded land to cassava.

Table 7.5 shows the results of the calculations for each category of LUC and CC and reports the findings as either an increase or decrease in GHG emissions from the production pattern prior to the planting of cassava. In the table the sign:

- (+) denotes a bonus, i.e. actual emission reduction if cassava is planted;
- (–) indicates an increase in emissions.

TABLE 7.5

GHG emissions for LUC and CC into cassava production

Parameter	Maize to cassava	Rice to cassava	Sugar cane to cassava	Pasture/set aside to cassava	Unused/degraded to cassava
	tonsCO_{2eq}/ha	tonsCO_{2eq}/ha	tonsCO_{2eq}/ha	tonsCO_{2eq}/ha	tonsCO_{2eq}/ha
Soil carbon IPPC	0	-7.389	0	-4.052	+1.210
Carbon stock EU	0	+1.0	-3.0	+1.30	+1.60
Methane emissions rice	0	+0.87	0	0	0
Non CO_2 burning 50 percent	0	(+0.113) +0.057	(+ 0.292) +0.146	0	0
N_2O difference for mineral fertilizer	0	- 0.025	+0.488	-0.244	- 0.244
Total value	0	-5.487	-2.366	-2.996	+2.566
Estimated share and type of GHG variation	80% (no change)	5% (increase)	5% (increase)	5% (increase)	5% (decrease)
Agricultural production scenario	**gCO_{2eq}/MJ**	**gCO_{2eq}/MJ**	**gCO_{2eq}/MJ**	**gCO_{2eq}/MJ**	**gCO_{2eq}/MJ**
Low input level	0	-69.76	-30.08	-38.09	+32.62
Medium input level	0	- 44.57	-19.22	-24.33	+20.84
High input level	0	-32.09	-13.84	-17.52	+15.01

Source: JGSEE.

In terms of CC from maize to cassava there was no observable difference in the calculated emissions. In Table 7.5 the shift from maize is equated with the GHG neutral action of replanting cassava.

The shift from rice to cassava shows the greatest impact in terms of GHG emissions. In total, GHG emissions associated with this type of CC are found to increase by a rate of 5.5 tonsCO_{2eq}/ha. The largest observable change is in soil carbon. While other measures show improved GHG outcomes associated with the change from rice to cassava, they are not enough to offset the emissions arising from changes in the soil carbon.

A CC from sugar cane to cassava does not change the soil carbon (because of the similar production methods), but the shift may reduce the overall carbon stocks (because sugar cane is more productive than cassava). Taking into account small gains associated with non CO_2 burning and N_2O-formation due to the differences in fertilizer application, final GHG emissions for the CC from sugar cane to cassava were found to increase by 2.4 tonsCO_{2eq}/ha.

In terms of LUC, different results were returned for each category analysed. For a change from set aside land or pasture to cassava, a calculated increase in carbon stock is not enough to offset the increased emissions arising from changes to the soil carbon. Overall it is anticipated that this category of land use change would result in increased GHG emissions of three tonsCO_{2eq}/ha. However, in the case where unproductive or unused/degraded land is shifted to cassava cultivation, biomass production is found to increase both soil carbon and carbon stock, which result in reduced emissions of 2.6 tonsCO_{2eq}/ha.

As any LUC and CC associated with cassava expansion will likely come under a number of the categories identified, a crude model was developed to estimate the total average value for changes in GHG emissions associated with a future expansion of cassava production in Thailand. Using existing information sources and data gathered during the field survey, it was estimated that demand for ethanol production from cassava could influence an additional area of up to 200 000 hectares. Subsequently, based on information and observations collected during the field surveys, a share was assigned to each category of LUC or CC to denote the type of change expected on the additional land area allotted to cassava. The average increase in GHG emissions associated with cassava expansion in Thailand comes to 0.415 tonsCO_{2eq}/ha.

New values can be calculated by adding the calculated GHG emissions from LUC and CC in Table 7.5 to the figures already established for cassava production in Table 7.4.

TABLE 7.6

GHG emissions for agricultural production scenarios of cassava

Agricultural production scenario	No CC or LUC or maize to cassava	Rice to cassava	Sugar cane to cassava	Pasture/set aside to cassava	Unused/ degraded to cassava
	gCO_{2eq}/MJ	gCO_{2eq}/MJ	gCO_{2eq}/MJ	gCO_{2eq}/MJ	gCO_{2eq}/MJ
Low input level	6.93	76.69	37.01	45.02	-25.69
average case			*12.21*		
Medium input level	5.43	50.00	24.65	29.76	-15.41
average case			*8.79*		
High input level	10.87	42.96	24.71	28.39	-4.14
average case			*13.30*		

Source: JGSEE.

Table 7.6 displays details of the final GHG emissions values adjusted to account for LUC and CC. As demonstrated above, CC from rice and sugar to cassava and LUC from set aside and pasture land to cassava have a dramatic effect on the final GHG balance. Note that due to the higher yield in the high input agriculture scenario, the increase in GHG emissions of a CC from rice to cassava is not as great as in the low input scenario. LUC from unused and degraded land could help to reduce the emissions but the effects are greater in the low and medium input scenario than in the high input scenario.

7.2.1.3 GHG emissions in cassava dried-chip production

To properly account for cassava ethanol production processes that employ chips as feedstock rather than cassava root, further analysis was conducted to quantify the GHG emissions and energy requirements for this additional step in the production process. Of the existing cassava-based ethanol production facilities in Thailand, all but one use cassava chips as feedstock.

Generally, chipping and drying occurs at sites proximate to cassava plantations. For the purpose of this analysis the chipping process was assumed to include transport of 30 km from the farm collection point to the chipping operation. Cassava chipping is carried out by tractors while drying takes place afterward in the sun. In fact, solar energy is the main energy input into the chipping and drying process followed by diesel. Using existing data that was verified with field visits a series of average values was produced for inclusion in GEMIS.

The final results for the process up to this point (i.e. chipping, including agricultural production) are shown in Table 7.7.

TABLE 7.7

Emissions and energy demand for cassava production and chipping process

Chipping and agricultural production scenario	Emissions						Energy requirement	
	CO_{2eq}	CO_2	CH_4	N_2O	SO_{2eq}	TOPP	Non RE	Renewable
	g/MJ	g/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	MJ/MJ	MJ/MJ
Chip -Low input level	9.14	7.80	5.07	4.12	77.29	96.68	0.113	0.688
Chip -Medium input level	8.11	6.97	4.45	3.51	69.78	87.16	0.100	0.688
Chip -High input level	11.85	8.41	7.40	11.03	84.07	97.56	0.123	0.688

Source: JGSEE.

The results range from between nine and roughly 12 gCO_{2eq}/MJ of chip (including agriculture related emissions), while the fossil energy input is between 0.10 and 0.12 MJ/MJ of chip.

7.2.1.4 GHG emissions in cassava-based ethanol processing

The different production configuration scenarios used to construct the LCA for cassav-based ethanol are the same as those specified in Chapter 6, Table 6.3. These scenarios differ in terms of type of power source, total energy requirements and physical set up (i.e. co-located or off-site refinery). To account for the final ethanol processing step, each of these scenarios is then combined with both the low and high level of inputs scenarios in the previous sections to develop a range of comparable output values. As there is little difference between the low and medium agriculture input scenarios in terms of overall GHG emissions and energy requirements, the medium one is omitted for ease of comparison.

As with the previous steps in production process, a mix of available data and findings from the field survey was introduced into GEMIS to calculate the final GHG emission and energy requirement values. The final results for GHG emissions and energy requirement including the ethanol processing step are presented in Table 7.8. The data refers to one MJ of ethanol. For reference the GEMIS calculations for gasoline in Thailand are also presented.

The results indicate that the main contributor to GHG emissions from cassava-based ethanol production is the refining process as opposed to agricultural inputs. The difference in total GHG emissions between low and high level of agricultural inputs under each production configuration is minimal.

The renewable energy configuration displays the best results in terms of GHG emissions and energy balance. The use of bagasse for steam and electricity from the co-located sugar mill increases the renewable energy contribution from 1.3 to 1.8 MJ/MJ, which results in the use of less fossil energy. The renewable energy requirement is greater than 1 because, as noted in previous sections, the renewable energy input used in the agricultural production of fresh cassava is one. The additional fraction of renewable energy required can be attributed to conversion and loss of mass along the production chain.

Due to reliance on mineral coal for power, the low efficiency fossil configuration associated with low level of agriculture inputs has the highest calculated GHG emissions of all the scenarios at 111 gCO_{2eq}/MJ of cassava ethanol. The energy balance for this scenario is also negative as total fossil energy consumption per unit is more than 1.2 MJ/MJ. This means that the production of one MJ of ethanol requires 1.2 MJ of fossil energy. The low efficiency fossil configuration displays greater emissions and a worse energy balance than fossil gasoline production in Thailand.

In comparison, the medium efficiency fossil configuration uses nearly 50 percent less coal per unit output of ethanol. This halves the final emissions per unit of output when compared to the low efficiency fossil configuration. The reduced energy requirement of 0.67 MJ/MJ also means that energy savings are generated

TABLE 7.8

Emissions and energy demand for cassava-based ethanol processing

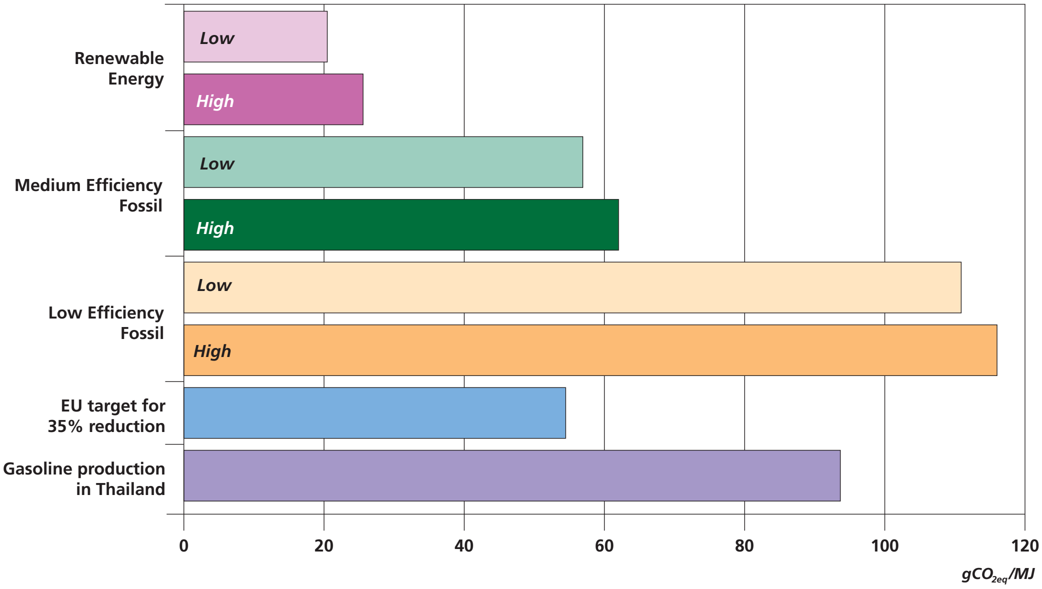
Ethanol production configuration	Level of inputs	Emissions						Energy requirement	
		CO_{2eq}	CO_2	CH_4	N_2O	SO_{2eq}	TOPP	Non RE	Renewable
		g/MJ	g/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	MJ/MJ	MJ/MJ
Low Efficiency Fossil	Low	110.90	108.11	16.41	8.16	1035.56	228.82	1.216	1.307
	High	116.01	109.26	20.80	21.18	1048.31	290.46	1.234	1.307
Medium Efficiency Fossil with waste water management	Low	56.92	54.11	16.43	8.21	523.12	254.68	0.668	1.309
	High	62.02	55.26	20.82	21.23	535.87	256.33	0.686	1.309
Renewable Energy	Low	20.46	16.39	31.97	11.28	393.77	361.98	0.236	1.790
	High	25.57	17.54	36.37	24.30	406.53	363.64	0.254	1.790
Gasoline production Thailand	N/A	93.66	93.06	20.09	0.46	942.88	1 328.42	1.223	0.005

Source: JGSEE.

when compared to fossil gasoline. However, in both fossil scenarios the non-renewable energy requirements are substantial. This has particular impact when evaluating cassava ethanol produced in Thailand against the EU sustainability criteria in terms of final GHG emissions (Figure 7.1).

FIGURE 7.1

GHG emissions of different cassava-based ethanol configurations



Source: JGSEE.

When compared against the EU sustainability criteria, cassava ethanol produced in Thailand performs poorly. While the renewable energy configuration comfortably meets the emission reduction measures, neither the low efficiency fossil nor medium efficiency fossil production configurations meet the EU target. The renewable energy model, which makes use of co-located bagasse power generation and industrial biogas, is the only configuration that would be suitable if Thailand looked to export cassava ethanol to the EU in the future.

At present biofuels produced where LUC has taken place are not considered eligible for import into the EU. However, the particular attention in this analysis paid to LUC and CC allows for some evaluation against the EU sustainability criteria to be made.

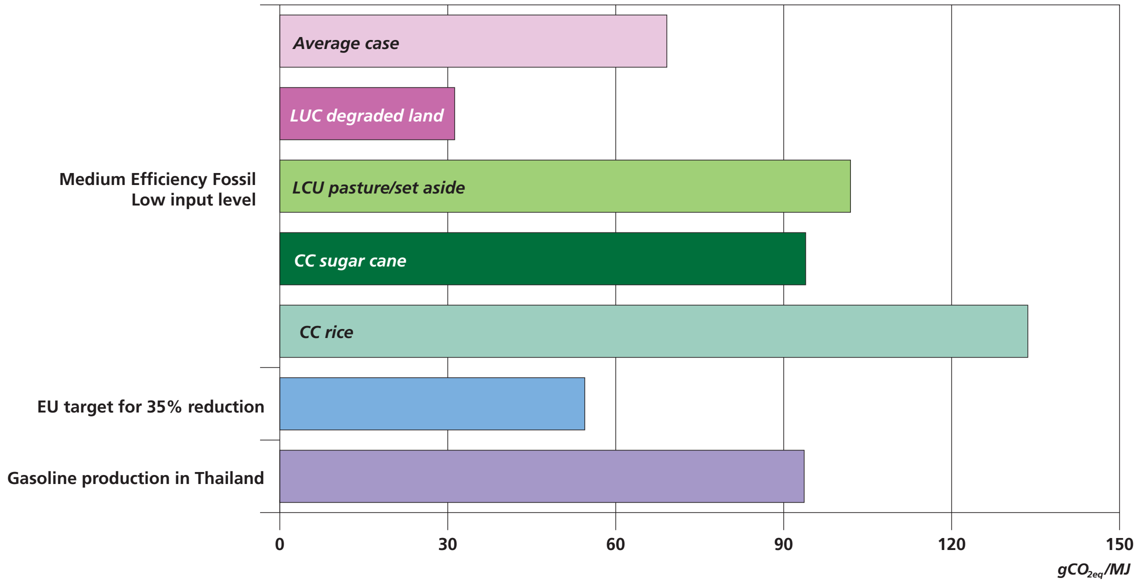
To understand how LUC and CC might affect cassava ethanol's performance against the EU sustainability criteria, LUC and CC scenarios were integrated into the medium efficiency fossil and renewable energy production configurations with low level inputs in cassava production. The results for both configurations are displayed in Figure 7.2 and Figure 7.3 respectively.

The addition of LUC and CC to the medium efficiency fossil configuration generally results in dramatic growth in total GHG emissions per unit of output. In the case of CC to rice and sugar and LUC to set and pasture land, final GHG emissions grow to a level far in excess of the EU sustainability target and the emissions value for gasoline. While using the average calculated value for LUC and CC delivers emissions less than fossil gasoline, the final value is still in excess of the EU target. Only a shift to degraded land improves the emissions profile in manner that meets the EU sustainability target.

The results improve under the renewable energy production configuration. While the calculated emissions for CC from rice, sugar and set aside or pasture land are still above the EU emissions reduction target, the average value scenario is well below this level. In the case of LUC from degraded land a net GHG reduction is created.

FIGURE 7.2

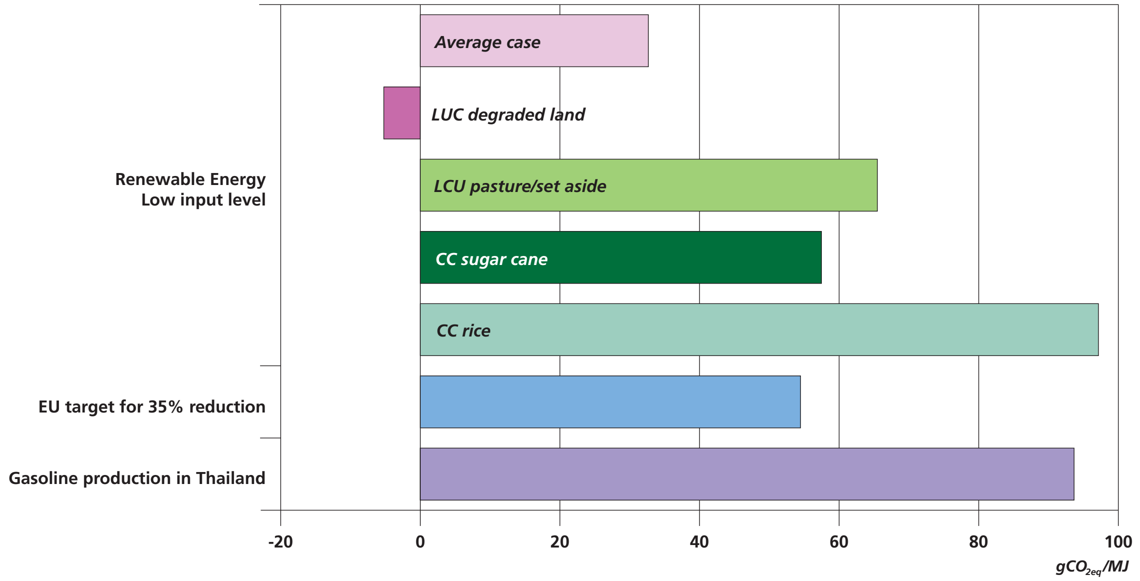
Influence of LUC and CC on the medium efficiency fossil scenario



Source: JGSEE.

FIGURE 7.3

Influence of LUC and CC on the renewable energy scenario



Source: JGSEE.

7.2.2 GHG emissions of sugar-based ethanol

The sugar sector in Thailand produces ethanol from molasses and, in special instances, raw sugar juice. The agricultural production step involves the production of sugar cane, the transport of cane to the sugar factory and the crushing of cane. Crushing of the sugar cane also produces raw juice. The next step in the process is associated with sugar production, which also produces molasses as a secondary product. Subsequently, the molasses is transported to a refinery for ethanol production. With sugar juice ethanol production method the sugar product is bypassed. Both cases are considered for this analysis.

The inputs for the production process are fertilisers and pesticides/herbicides. Energy inputs are diesel in agriculture for field operations and harvest. The transport energy component is calculated using details of the transport mode (type of transport vehicle) and distance travelled. At the sugar mill energy is needed for the mill operation and sugar production. The energy is produced by using bagasse, which is a by-product of the crushing operation. This bagasse is combusted in boilers and steam and electricity are produced simultaneously. As GEMIS only allows for linear processes, a credit is given for steam consumption where applicable. This means that electricity produced from bagasse is the only input into GEMIS. By allocating a credit for steam power generation this energy source can be adequately accounted for while avoiding double counting.

The LCA analysis is reported for the four scenarios developed in Chapter 6 (Table 6.6). For the purpose of comparison hypothetical scenarios have also been developed that use fossil energy as the main source of power for the refining step. These scenarios are presented in Table 7.9.

The results of the LCA analysis for all six sugar ethanol scenarios are presented in Table 7.10. The sugar on-site scenario delivers the lowest GHG emissions at 22.02 gCO_{2eq}/MJ. This is closely followed by the on-site production configuration of ethanol from molasses at a sugar mill. This configuration most closely represents the actual production configuration employed by most ethanol producers in Thailand. For the scenario where a portion of the molasses is transported to the ethanol refinery, additional energy is required

TABLE 7.9

Additional sugar-based ethanol processing scenarios

Production Scenario	Description
Sugar – Fossil	■ 182.5 million litre capacity powered by grid, electricity and/or coal ■ Ethanol produced from sugar juice in off-site facility ■ Theoretical scenario – no actual example in Thailand
Molasses – Fossil	■ 73 million litre capacity powered by grid, electricity and/or coal ■ Theoretical scenario – no actual example in Thailand

TABLE 7.10

Emissions and energy demand for sugar-based ethanol

Ethanol production configuration	Emissions equivalent						Energy requirement		
	CO_{2eq}	CO_2	CH_4	N_2O	SO_{2eq}	TOPP	Non RE	Renewable	Others
	g/MJ	g/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	MJ/MJ	MJ/MJ	MJ/MJ
Molasses – On-site	22.72	11.97	90.37	29.29	682.62	605.15	0.172	2.210	0.0007
Molasses – Stand Alone	27.87	17.10	89.48	29.44	709.51	643.23	0.241	2.211	0.0008
Molasses – Rice Husk	28.93	17.79	89.08	30.71	700.60	632.36	0.250	2.626	0.0008
Molasses – Fossil	78.85	69.09	69.76	27.56	1024.05	551.95	0.805	1.684	0.0008
Sugar – On-site	22.02	11.94	71.20	28.53	529.56	475.75	0.172	2.028	0.0007
Sugar – Fossil	73.00	69.92	51.48	26.64	844.24	384.46	0.736	1.501	0.0008
Gasoline production Thailand	73.00	69.92	51.48	26.64	844.24	384.46	0.736	1.501	0.0008

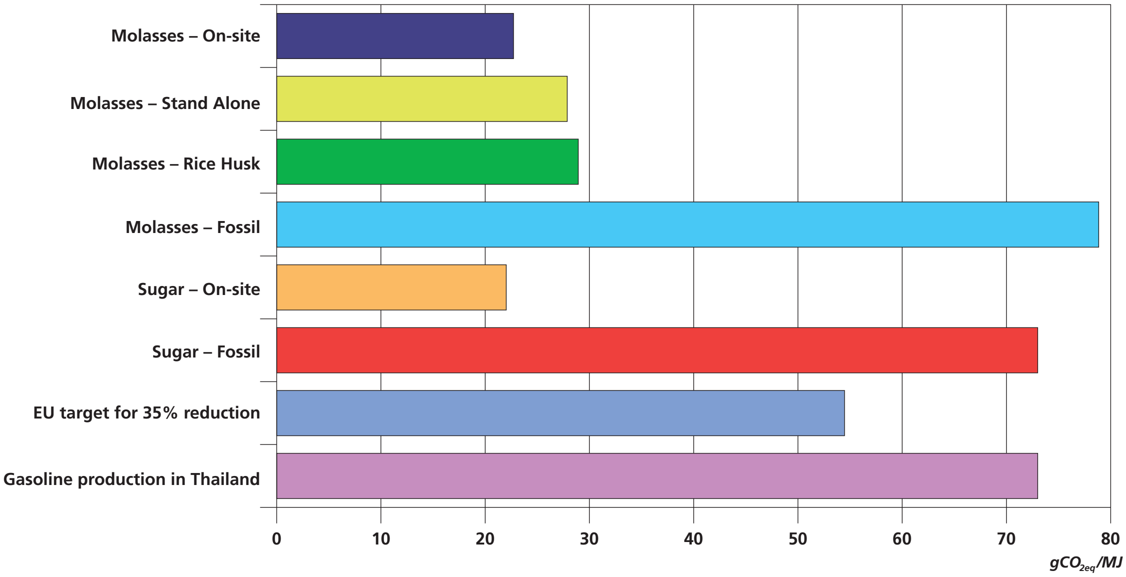
Source: JGSEE.

for transport which results in higher fossil (Non RE) energy requirements and, consequently, slightly higher GHG emissions (27.87 gCO_{2eq}/MJ).

Looking at the energy requirements in more detail, it can be seen that if renewable energy is used as the main source of power total energy requirements (Non RE and RE) are generally greater than the fossil configurations. This is because the conversion of renewable materials to energy is less efficient than when using fossil fuels. However, while fossil fuels are more efficient in terms of energy, their use has significant increases final GHG emissions. In each case where fossil fuel is used as the main energy source in the refining step, calculated GHG emissions reach above 70 gCO_{2eq}/MJ. In contrast, all renewable energy production configurations record final GHG emissions of less than 30 gCO_{2eq}/MJ of ethanol produced (Figure 7.4). Also, from Figure 7.4 it can be observed that sugar-based ethanol produced in Thailand performs well against the EU sustainability criteria targets. Each scenario using renewable energy produces GHG emissions well below the threshold values.

FIGURE 7.4

GHG emissions of different sugar-based ethanol configurations

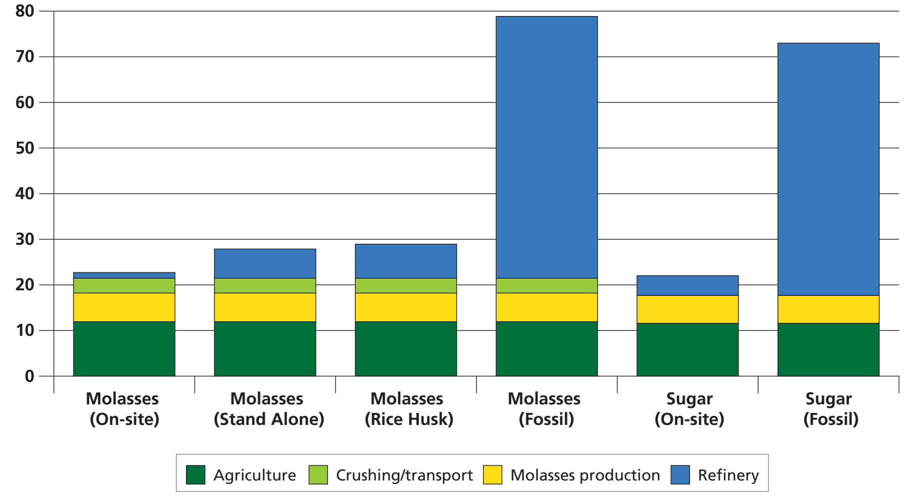


Source: JGSEE.

Table 7.10 demonstrates that fossil energy savings are possible under each sugar ethanol scenario when compared to fossil gasoline. However, use of a fossil fuel refinery considerably decreases net energy savings. Also in the case of sugar-based ethanol the refining step is the largest contributor in terms of GHG emissions. The type of energy used to power the final processing step is the key determinant of which processing step contributes most to final GHG emissions. However, where renewable energy is used in the refining step, agriculture becomes the largest contributor to final GHG emissions.

FIGURE 7.5

Breakdown of GHG emissions by step for sugar-based ethanol scenarios



Source: JGSEE.

7.2.3 GHG emissions of biodiesel

As with the economic analysis presented in Chapter 6, other biodiesel production chains are also analyzed for the purpose of comparison. In addition to the scenarios presented in Chapter 6 (Table 6.8), two additional biodiesel scenarios were developed for the purpose of the LCA analysis. Further details of these scenarios are available in Table 7.11.

The production steps used to develop the LCA for palm oil biodiesel included agricultural production of oil palm, transport of oil seed and processing of CPO and final biodiesel refining. Unlike the analysis for cassava, land use and crop change is not considered in detail. However, the issue is touched upon briefly at the end of the chapter.

Besides CPO, waste cooking oil and stearine are also considered as potential biodiesel feedstock. Stearine is a by-product extracted from crude palm oil during conversion into refined palm oil and is available in Thailand on a limited scale. From an LCA perspective stearine and waste cooking oil have the advantage of being emissions free because all emissions associated with their production are already allocated to other industrial processes. In developing the LCA for these alternative feedstock scenarios, only the collection and transport is considered in the pre-refining step. However, a disadvantage of using these feedstocks is that they possess lower conversion ratios and require higher material and energy inputs in the refining process.

The input values for each biodiesel scenario in GEMIS were derived from existing research and field surveys.

The results of the LCA analysis for all six biodiesel scenarios are presented in Table 7.12. Each scenario analyzed is found to generate less GHG emissions than fossil diesel. The large scale CPO production

TABLE 7.11

Additional biodiesel processing scenarios

Production scenario	Description
Stearine – Large Scale	■ 146 million litre capacity powered by grid, electricity and/or coal
Waste Cooking Oil – Large Scale	■ 146 million litre capacity powered by grid, electricity and/or coal

TABLE 7.12

Emissions and energy demand for biodiesel

Biodiesel production configuration	**Emissions equivalent**						**Energy requirement**		
	CO_{2eq}	**CO_2**	**CH_4**	**N_2O**	**SO_{2eq}**	**TOPP**	**Non RE**	**Renewable**	**Others**
	g/MJ	**g/MJ**	**mg/MJ**	**mg/MJ**	**mg/MJ**	**mg/MJ**	**MJ/MJ**	**MJ/MJ**	**MJ/MJ**
CPO – Large Scale	20.79	14.64	37.06	17.89	187.19	104.72	0.315	2.666	-0.029
CPO – Small Scale	23.69	15.74	79.03	20.70	178.92	116.74	0.578	3.120	-0.104
Stearine – Large Scale	7.35	6.71	26.16	0.11	67.74	21.25	0.251	1.296	0.9486
Waste Cooking Oil – Large Scale	7.40	6.76	26.18	0.12	68.24	21.79	0.255	1.299	0.9486
Waste Cooking Oil – Small Scale	9.60	8.25	54.90	0.30	59.21	42.93	0.477	0.010	1.0433
Multi-Feed – Large Scale	17.03	12.43	34.02	12.92	153.77	81.39	0.297	1.920	0.2451
Diesel production Thailand	*93.10*	*92.46*	*21.94*	*0.46*	*988.66*	*1,327.30*	*1.223*	*0.005*	*0.0002*

Source: JGSEE.

configuration, which is the configuration most indicative of the current biodiesel industry in Thailand, generates final GHG emissions of 20 gCO_{2eq}/MJ. This figure is far less than the 93 gCO_{2eq}/MJ generated by fossil diesel. Under the multi-feed, stearine and waste cooking oil scenarios final calculated GHG emissions are reduced even further.

Interestingly, the small scale CPO scenario generates the highest level of GHG emissions per MJ of biodiesel produced. This is due to the fact that the small scale operation requires more energy per unit of output, which results in higher emissions. Energy requirements for the small scale production configuration reach 0.58 MJ/MJ, while the large scale CPO operation requires only 0.32 MJ/MJ. The small scale scenario was also found to require more methanol input per unit of output and produce more by-products such as raw glycerine and non-converted vegetable oil. These all have a negative effect on the final energy balance and GHG emissions.

In terms of energy balance biodiesel is shown to generate fossil energy savings when compared to fossil diesel production in Thailand. The magnitude of these savings is generally higher than those possible with the ethanol production configurations assess previously because final energy requirements in the ethanol refining process are much higher than those for biodiesel. As a result, biodiesel production generally results in more GHG emissions reductions than ethanol.

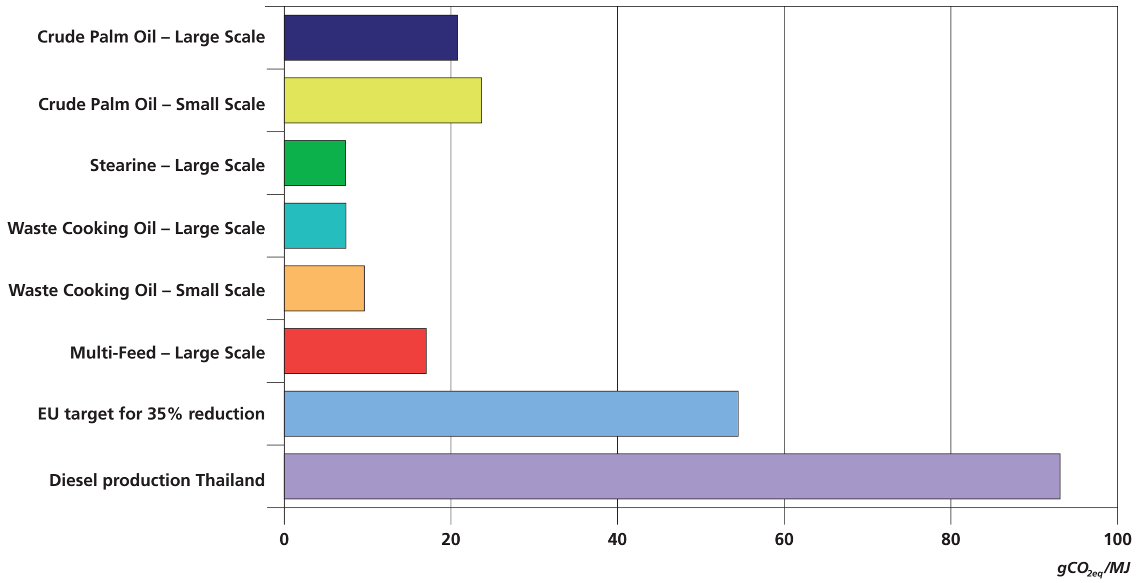
Further, in contrast to the ethanol production configurations, the largest contributor to GHG emissions in the biodiesel production is agriculture – except in the scenarios where waste cooking oil and stearine are used as feedstock. In the agriculture production step, GHG emissions are dependent upon the application of fertilizer, product transport and machinery operation.

As can be observed in Figure 7.6, each of the biodiesel scenarios analyzed exceeds the EU sustainability requirements for GHG emissions reductions. However, it should be noted that for the purpose of this study, potential GHG emissions from untreated wastewater ponds is not included in the final emissions calculation. Biodiesel production results in considerable amounts of wastewater that is high in organic matter. This waste generates methane that is released into the atmosphere if not treated. Accounting for these emissions in could add as much as 21.28 gCO_{2eq}/MJ to each scenario. While adding this factor to each scenario still results in total GHG emissions per MJ at levels less than the EU target, the emissions increase under each scenario is considerable. One viable option to address this problem is to divert waste water for use in industrial biogas facilities.

During the field survey a number of other opportunities were identified to capture further emissions reductions at every step of the production chain through better process efficiencies and the greater use of by-products for energy. Waste fibres and kernels from empty fruit bunches were identified as a particularly rich source of fibre for renewable energy generation. Figure 7.7 provides an overview of the estimated additional energy in megawatt (MW) that could be sourced from by-products in the production of CPO at a medium sized processing mill that processes 45 tons of fresh fruit bunch per hour.

FIGURE 7.6

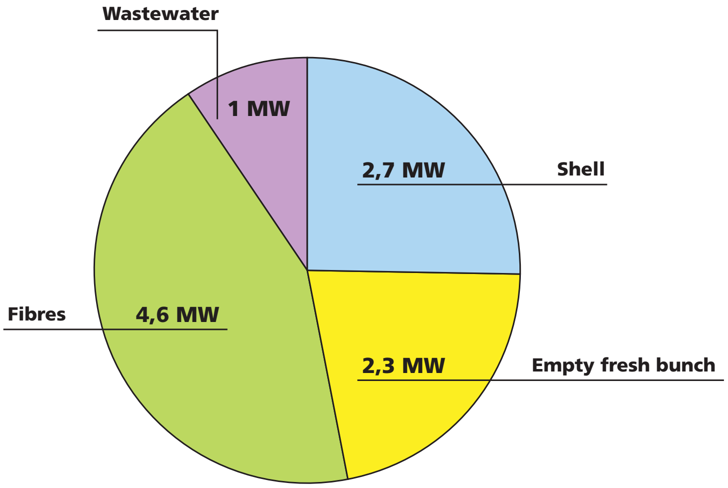
GHG emissions of different biodiesel configurations



Source: JGSEE.

FIGURE 7.7

Renewable energy potential of medium sized CPO mill



Source: JGSEE.

Table 7.13 summarizes how the GHG emissions of the large scale CPO production configuration could be affected by greater use of renewable energy through a wastewater biogas plant and, alternatively, land use change. From this table it can be observed that capturing emissions from wastewater ponds with biogas project can reduce final GHG emissions by between 11 and 15 gCO_{2eq}/MJ of biodiesel. To assess the potential effects of land use change two sets of default values are used. One for a land use change from secondary forest and the other for a change from degraded or unused land. In the case of a land use change from secondary forest, total emissions increase by 80 gCO_{2eq}/MJ of biodiesel taking the overall level well above the EU sustainability threshold value. In the case of a change from degraded or unused land the opposite affect is observed. Total emissions decrease by 100 gCO_{2eq}/MJ of biodiesel resulting in the generation of net GHG emissions reductions.

TABLE 7.13

Comparison of GHG emissions for CPO large scale configurations

CPO configurations Process	With biogas project gCO_{2eq}/MJ	No biogas use gCO_{2eq}/MJ	Fossil mill gCO_{2eq}/MJ
Agriculture	+11.47	+11.47	+11.47
Oil mill	+1.67	+1.67	+23.85
LUC – Secondary forest	+79.11	+79.11	+79.11
LUC - Degraded/unused land	-100.92	-100.92	-100.92
Open pond	n.a.	+21.28	+21.28
Methane mitigation*	-12.90	n.a.	n.a.
Refinery	+7.65	+7.65	+7.65
Total w/o LUC	**+7.89**	**+42.07**	**+64.25**
Total with LUC forest	**+87.00**	**+121.18**	**+143.36**
Total with LUC degraded	**-93.03**	**-58.85**	**-36.67**
Requirements for EU	*+ 54.47*	*+ 54.47*	*+ 54.47*

* Based on methodology for the CDM mechanism, in Thailand's projects this results in the range of 10.91 to 14.89 gCO_{2eq}/MJ. The value used in this calculation is the average.
Source: JGSEE.

7.3 CONCLUSIONS

- *Biofuels produced in Thailand display measurable GHG benefits when compared to fossil fuels*. In general each biofuel production scenario considered delivered GHG emissions reductions when compared to fossil fuels. Biofuels were also generally found to deliver energy savings when compared to fossil fuels. However, while this indicates that biofuels produced in Thailand hold some benefit from a policy perspective, some of the production configurations assessed do not meet the EU sustainability targets for GHG emissions reductions. The research highlights some areas where policy interventions may further improve the sustainability of biofuels produced in Thailand.
- *The refining process is the most critical determinant of the overall GHG balance of biofuels*. The type of energy used to power the refining process has critical bearing final total GHG emissions, particularly in the case of ethanol. The choice between a fossil energy and renewable energy refinery was found to be the deciding factor regarding whether a unit of ethanol was able to meet the EU sustainability targets for GHG emissions reductions. In the case of biodiesel, the lower energy requirement at the refining stage means that fossil fuel refineries are still a viable and sustainable option over the short to medium term. The findings of this report present considerable evidence in favour of policies that would encourage biofuel production facilities to improve fossil energy efficiency and adopt renewable energy technologies to both power refinery operations and manage process waste streams.

- *Agriculture is also a key contributor to the GHG profile particularly when land use and crop changes are involved*. In most cases assessed, agriculture was the next largest source of GHG emissions after the refining step. In the case of biodiesel, agriculture was found to be the largest contributor to final GHG emissions. The field survey and subsequent analysis indicate that improving the productivity of feedstock agricultural systems will reduce final GHG emissions per unit of biofuel produced. Where land and crop use change are involved in the agricultural production process, final GHG emissions can increase dramatically. Expansion of land use and crop changes for biofuel feedstock production needs to be closely monitored. Based on the research produced in this report, once particular types of land or crop use change are involved in the production of feedstock crops, the final product quickly loses any GHG emission or energy balance advantage over fossil fuels. While some form of land use or crop change is expected to accompany the anticipated growth in Thailand's biofuel output, this report identifies particular categories of change that should be avoided and even discouraged.
- *The Thai bioenergy sector could reduce emissions through better agricultural practices and by using by-products for energy*. While biofuels produced in Thailand were found to deliver emissions benefits when compared to fossil fuels, the field visits and subsequent analysis identified process and technology improvements that could be used to further reduce GHG emissions. As noted above, measures to improve agricultural productivity such as the targeted application of additional inputs could lead to yield improvements that would reduce GHG emissions per unit of biofuel produced. In addition, better utilization of agricultural wastes such as rice husk, bagasse and empty fruit bunch for power generation will also lead to emissions reduction. Better management of process wastes such as water could also provide similar opportunities for further emissions reductions.

7.4 REFERENCES

EU. 2009. *Rules for calculating the greenhouse gas impact of biofuels, other bioliquids and their fossil fuel comparators*, Annex VII in Directive 2009/28/EG: Promotion of the use of energy from renewable sources, Brussels.

IPPC. 2006. *2006 IPCC guidelines for national greenhouse Inventories*, Volume 4, Agriculture, Forestry and Other Land Use, IGES, Japan.

MoE. 2009. *Alternative Energy Promotion Measures*, Ministry of Energy, Bangkok. Available at www.dede.go.th/ dede/fileadmin/upload/pictures_eng/pdffile/AE_Promotion_Measures.pdf.

Nguyen T.L.T., Gheewala S. H. & Garivait S. 2007. *Full chain energy analysis of fuel ethanol from cassava in Thailand*, Environ. Sci. Technol., 41, 4135-4142

Oeko-Institut. 2004. *Global Emission Model for Integrated Systems*, free software, description, examples and handbook available at www.gemis.de.

Raphael B. 2008. *Environmental analysis of the production chain of biodiesel from palm oil and discarded oil in Thailand*, internship report, JGSEE, Bangkok.

Rauch R. 2007. *E3Agro Project: impact assessment report*, Chapter 4.1 and 4.2, GTZ, Bangkok.

UBA. 2008. *Criteria for a sustainable use of bioenergy on a global scale*, Federal Environmental Agency, Dessau-Roβlau, Germany.

7.5 APPENDIX

Global Emission Model for Integrated Systems

GEMIS is the acronym for Global Emission Model for Integrated Systems. The model can perform complete life-cycle computations for a variety of emissions, and can determine the resource use. In addition, GEMIS analyzes costs - the corresponding data of the fuels as well as cost data for energy and transport processes are included in the database. GEMIS allows also assessing the results of environmental and cost analyses: by aggregation of emissions into so-called CO_2 equivalents, SO_2 equivalents, and tropospheric ozone precursor potential (TOPP), and by a calculation of external costs.

In GEMIS 4.3, emission standards are included - one can easily check if combustion processes comply with national and international emission standards, and filter the database for suitable processes. The GEMIS 4.3 database offers information on energy carriers (process chains, and fuel data) as well as different technologies for heat and electric power generation. Besides fossil energy carriers (hard coal, lignite, oil, natural gas), also renewable energies, household waste, uranium, biomass (e.g. fast growing woods, rape) and hydrogen are covered in GEMIS. Data on various material process chains (above all for construction materials), and processes for transport services, i.e. cars (gasoline, diesel, electricity, biofuels), public transport (bus, train) and airplanes as well as processes for freight transport (trucks, LDVs, train, ships and pipelines) are available in the database. A novelty is the processes for waste treatment (disposal), and the monetary processes which represent aggregated data for the sectors of the economy. The process data are given now for a variety of different countries, and a special set of data (called "generic") refer to the situation in developing countries. Users can adjust each and every data item to their needs, or work with the core database which covers more than 8 000 processes in over 20 countries.

The GEMIS model has been demonstrated on various occasions. The main issue in using this model is a sophisticated and structured approach, as the model does not check on conformity and correctness of the input data. The main function of GEMIS is the definition of products and processes. Different processes can be connected to complete production chains, but the user’s responsibility is to guarantee correct input data and relationships as GEMIS only calculates and aggregates what input it sees. A wrong figure somewhere in the chain or a misused connection could change the result dramatically. The user therefore needs to understand the whole approach and should have at least an understanding of the basic function and the range of expected output values.

The major advantage of GEMIS is a structured data bank application with established calculation procedures, containing a large set of data on all different aspects of LCA including environmental impact monitoring. Additional models need to be used in parallel with GEMIS including an economic model for the different conversion technologies of biomass-to-energy considered and a land use model for sustainability assessment of the various scenarios considered in this project at a national scale.

CHAPTER 8

SOCIO-ECONOMIC ASPECTS

In previous chapters considerable attention has been directed towards assessing how the Thai Government's policies for development of the biofuel sector could impact upon the Thai agricultural sector, Thailand's natural resource base and the environment and Thai biofuel producers. The final element of the BEFS analysis is to consider how the Thai Government's plans for the biofuel sector could affect Thai households and the broader economy.

The impact of the biofuel sector at the household level is particularly important in determining the implications of biofuel development for food security and poverty reduction. Increased output of biofuels will potentially create new wealth generating opportunities for biofuel feedstock producing households. However, if increased activity in the biofuel sector also triggers general growth in the price of goods and services, particularly food, then those households outside the biofuel production chain will suffer a relative decline in income. Such a situation could be particularly acute for rural and urban poor who generally spend a greater proportion of their available income on food. In the case where households are living just above the poverty line, increases in the price of food may throw these households into poverty raising the risk of poor nutrition and future food insecurity.

Bioenergy could also have an effect in terms of the cost of energy. At a community level, bioenergy can promote development by reducing energy expenditures and providing more effective and timely delivery of energy and its related services. This could lead to the development of alternative opportunities for income generation.

The purpose of this chapter is to: 1) examine how changes in the price of agricultural commodities that could result from expansion of the biofuel sector will impact upon Thai households and the Thai economy as a whole; and 2) assess the potential benefits and barriers of small-scale bioenergy systems to their wider adoption in Thai rural communities.

8.1 THE METHODOLOGY

Over the last few years biofuel developments have been widely recognized, although to a varying degree, as one of the key drivers of the recent price surge and increased price volatility. In this context first generation bioenergy developments represent an additional source of demand for crop production which can lead to price increases.

The analysis in this chapter first looks at the impact of price changes on households and the broader Thai economy. The main assumption is that biofuels will create a new source of demand for biofuel crops and this demand will result in a rise in the price of these commodities and, possibly, other agricultural commodities. The methodology used for analysing the impacts of price changes is described in Sections 8.1.1 and 8.1.2.

In the second part of the chapter attention is given to small-scale community level bioenergy systems; specifically the benefits that could stem from these systems and the challenges involved in replicating successful small scale bioenergy projects. A description of the survey and the qualitative assessment of small-scale bioenergy systems is described in Section 8.1.3.

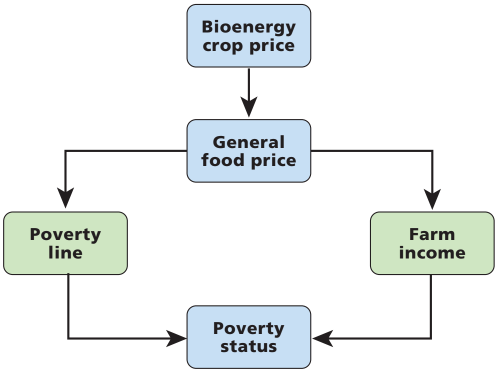
8.1.1 Microeconomic analysis

The microeconomic analysis focuses on how movements in the price of agricultural commodities and biofuel crops could impact on Thai household income, consumption and poverty. At the household level it is assumed that these impacts will exert themselves through the following two channels (Figure 8.1):

- *Channel 1: Cost of living*. Changes in food prices affect the cost of living of all Thai people. Changes in food prices have particular impact on poorer and low income households which generally spend a higher proportion of their income on food purchases. Generally, in the case of higher food prices, the incidence of poverty increases where the food poverty line grows at a greater rate than income. A poverty line is the base amount in baht per person per month of expenditure on a category of goods required to be considered out of poverty.
- *Channel 2: Incomes from agriculture*. For farmers who grow biofuel crops higher prices could translate into higher household income also lifting some farmers out of poverty as a result.

FIGURE 8.1

Impact of price variation of biofuel crops on Thai households



Source: TDRI.

The data used for this analysis is drawn from Thailand's Socio-Economic Survey (SES), which is the national household survey conducted annually by Thailand's National Statistical Office (NSO). Ideally, to isolate the specific impact of the biofuel sector, this analysis would isolate households that produce each biofuel crop and/or households that consume them and assess their net position with respect to each crop. Unfortunately, as income data collected for the SES is not disaggregated by crop, the micro analysis employed in this chapter assumes that the prices of biofuel crops generally move in the same direction as the prices of other food crops. Simply, instead of focusing on a specific biofuel crop, the analysis estimates the impact on households arising from a general increase in food prices.

A full example of the household level analysis was performed in Thailand (Somchai J. and Siamwalla A., 2009) and in Cambodia (FAO, 2010) for the rice sector only.

8.1.2 Macroeconomic analysis

The macro level analysis focuses on how movements in the price of agricultural commodities and biofuel crops can impact directly and indirectly on the Thai economy as indicated by measures such as economic growth, average price levels, household consumption and income and aggregate trade and investment levels. To conduct this assessment a computable general equilibrium (CGE) model was employed. CGE models are simulation-based economic models where economic agents optimize their consumer preferences and interact with other agents in market-clearing equilibrium manner.

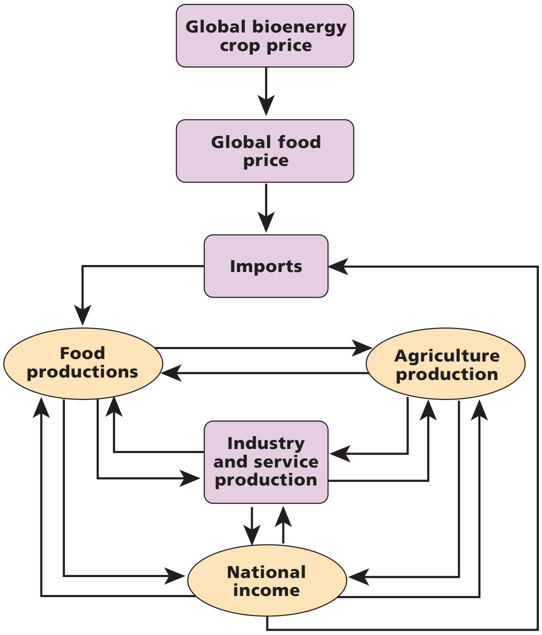
The CGE model used in this analysis was originally created by the Thailand Development Research Institute (TDRI) with financial support from the Asian Development Bank (ADB) to study the impact of organic agricultural development in Thailand (TDRI, 2009). The CGE model was constructed using 2005 data and a social accounting matrix comprising 488 accounts with 53 production sectors – 12 of which are agricultural production sectors.

As the CGE model employed for this analysis was not built specifically to study biofuels, the sectors involved in biofuel production are not separated out from those involved in food crop production. Fortunately, the production techniques of agricultural crops and biofuel crops generally differ only concerning the end use. Since the supply of agricultural produce for food and for energy is almost perfectly substitutable, it is assumed that biofuel crop prices will move also almost in unison with food crop prices. The model also assumes that Thailand is a price-taker when it comes to biofuel or food crops. This is because Thailand's share of global trade in each specific category of agricultural commodity is not considered large enough to affect the world price. The only potential exception to this assumption is rice.

As noted previously, it is assumed that as biofuels produced in Thailand will create an additional source of demand for biofuel crops, the effect of implementing the AEDP biofuel targets will be an increase in the price of these crops and food crops in general. In the absence of a separate biofuel sector, the CGE simulates this increase prices via the world price of biofuel and food crops.

FIGURE 8.2

Impact of price variation of biofuel crops on Thai economy



Source: TDRI.

An increase in the import price of food will affect the domestic economy through many channels (Figure 8.2). Firstly, domestic prices of food are pushed upward as domestically produced food products progressively substitute for imports. The exact magnitude of the increase depends on the elasticity of substitution between domestic and imported food products. Higher prices also provide incentive for supporting industries to increase output of products and services such as fertilizer, pesticides, energy, transportation, wholesale and retail services. This increase in output among agricultural and supporting sectors will also flow on to the broader economy and impact upon national income. Finally, price changes affect household demand for both domestically produced and imported goods.

8.1.3 A survey analysis of small-scale bioenergy practices

The purpose of this analysis is to identify the key factors of success underpinning best practice bioenergy development in rural communities. The analysis also looks to understand the types of challenges that need to be overcome to ensure new bioenergy developments work for rural communities. The analysis is supported by a qualitative survey that aims to capture the experience of a wide range of communities and document important lessons for other communities looking to implement their own bioenergy initiatives.

The qualitative survey was implemented in two parts:

1. *'Best practice' bioenergy rural projects are identified and surveyed.*

Following in-depth interviews with community leaders, villagers, government officials, and local NGOs and observation, a number of 'best practice' rural bioenergy projects are identified using the following criteria:

- The community has been producing bioenergy for a period greater than 12 months.
- The community has successfully secured necessary funding either through the sale of outputs or other support to continue to implement the project.
- The community had established some form of learning or outreach centre to educate other interested communities about its experiences with bioenergy.

In addition to the criteria above, care was taken to ensure that the 'best practice' communities were geographically far from each other so that differences in geographical settings could be captured in the analysis. It was also considered desirable that the communities identified as 'best practice' encompassed a wide range of possible bioenergy technology options.

2. *Replicating communities are identified and surveyed.*

Proximate communities which have attempted to replicate one of the 'best practice' cases were then identified and surveyed. Each community surveyed was then ranked in terms of the success of its attempts to replicate the 'best practice' case according to the following three categories:

- *Most successful* – The replicating community has established a functional bioenergy project for a period greater than 12 months and has established its own learning centre to educate other communities with evidence of successful additional replication.
- *Moderately successful* – The replicating community has established a functional bioenergy project and a learning centre.
- *Least successful* – The replicating community has not established a functional bioenergy project.

The establishment of a learning centre was considered a key indicator of success because it indicates a relative level of competence with bioenergy technologies and capacity to share experiences and knowledge regarding bioenergy.

Based on survey responses and observations in the field a range of data was collected to rank the surveyed communities and isolate common elements of success. Challenges and obstacles to the implementation were often found to be the result of an absence or restriction regarding one or more of the success factors. Generally, success factors and obstacles can be broken down into the following categories:

- *Context* - Identifying how the physical, institutional and policy context can encourage or impede bioenergy development.
- *Financial support* - Understanding how different sources of funding affect the ability of communities to adopt new bioenergy technologies.
- *Technical support* – Taking account of the technical skills required to successfully implement and operate the chosen bioenergy technology. An assessment of the technical support required also provides insight into the type and scale of capacity building required to successfully implement a successful bioenergy project.
- *Knowledge relating to specific technology and biofuels* - The presence or absence of a particular knowledge base can aid or hinder promising bioenergy development.
- *Institutional support* – Understanding how community networks, NGO, donors and government at all levels can influence bioenergy development.
- *Impact assessment* – A clear understanding of the desired outcomes and potential impacts of a bioenergy project can have important bearing on the success of that project.
- *Cost-benefit analysis* – Similarly, understanding the impacts of a particular bioenergy initiative in terms of potential costs and benefits ensures communities are better prepared to overcome any obstacles to implementation and manage expectations.

To further investigate the financial aspect of small-scale community-based bioenergy projects, a number of *zero-waste* bioenergy projects were assessed in terms of financial costs and benefits. Zero-waste bioenergy systems use crops to produce a range of outputs including energy, fertilizer and consumer goods. These systems are considered to offer great potential for rural communities to produce their own supply of energy and other energy related outputs in a sustainable manner. Zero-waste systems have been selected by the Thai Government for further investigation and development as part of the AEDP.

8.2 RESULTS

8.2.1 Impact of biofuels on households

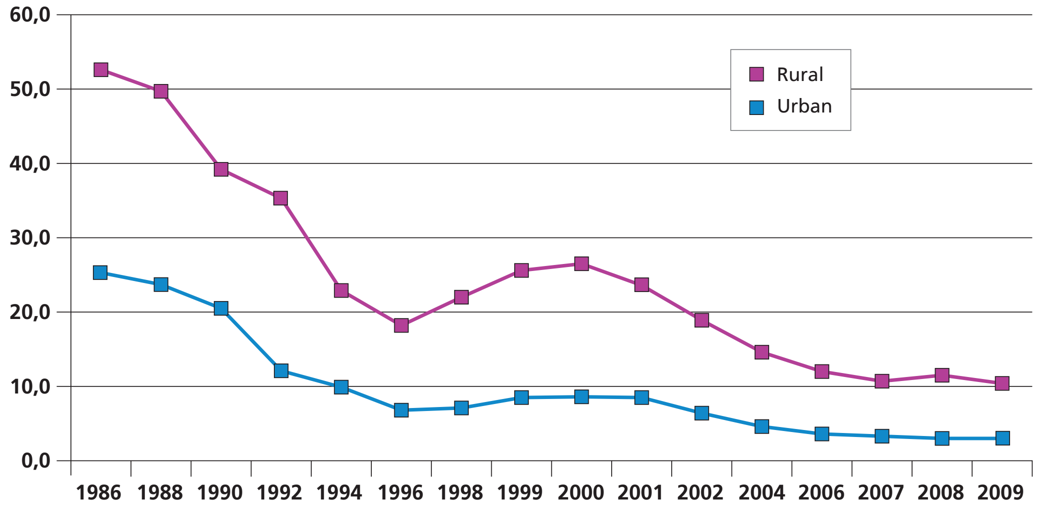
As discussed in Section 8.1.1, the impact of biofuel development on households is estimated by analysing the affect of a general rise in the price of agricultural goods; specifically food crops. For the purpose of this analysis it is assumed that changes in food prices will affect households through flow on changes to the food poverty line and farm income.

Before presenting the results it will be useful presenting background information on poverty and household economic conditions in Thailand to contextualise the analysis.

The poverty situation in Thailand has improved dramatically over the past two decades (Figure 8.3). However, pockets of poverty still exist throughout the country.

FIGURE 8.3

Poverty incidence by area, 1986-2009



Source: NSO - calculated from 2009 Socio-Economic Survey.

As can be seen in Table 8.1, and already reported in Chapter 2, the incidence of poverty in Thailand in 2009 was 8.12 percent with the vast majority of poor located in the North and Northeast regions of the country. The average food poverty line is generally higher than the non-food poverty line, except in Bangkok where there is a bias in consumption patterns toward more non-food items.

As noted previously a poverty line is the base amount expressed in bath per person per month (THB/person/month) of expenditure on a category of goods required to be considered out of poverty. In the discussion the poor is the household who cannot afford such minimum base amount of expenditure.

TABLE 8.1

Per capita income and expenditure, poverty line and incidence by region in 2009

Region	Income THB/person	Expenditure THB /person	Average poverty line Food THB/person/month	Non-food THB/person/month	Total THB/person/month	Poverty incidence Income %	Consumption %
Bangkok	13 446	8 463	917	1 218	2 135	1.84	0.86
Central	7 080	5 094	893	760	1 652	3.06	2.54
North	4 965	3 420	929	556	1 485	9.49	11.08
Northeast	4 339	3 127	957	517	1 473	13.89	13.67
South	6 707	4 464	970	577	1 547	5.22	4.72
Total	6 239	4 308	934	652	1 586	8.18	8.12

Source: NSO – calculated from 2009 Socio-Economic Survey.

In Thailand, the incidence of poverty is also greatest amongst agricultural households. As can be seen in Table 8.2 over 75 percent of Thailand's poor are engaged in agricultural production. While this might imply that biofuel production may provide an opportunity to lift some of Thailand's agricultural producers out of poverty, the largest segment of Thailand's agricultural poor produce rice as their only crop. This could severely limit the poverty reducing potential of the biofuel sector and even worsen Thailand's poverty situation if development of the sector were to lead to a broad increase in prices.

TABLE 8.2

Number of households by poverty status and economic sectors in 2009

Poverty status	Non-agricultural households	Agricultural households			Total
		No rice	Rice only	Rice and other crop	
Non poor	31 151 909	9 393 642	13 248 815	5 918 811	59 713 177
% Non poor	96.15	92.11	85.32	86.19	91.88
Poor	1 246 772	804 131	2 279 345	948 601	5 278 849
% Poor	3.85	7.89	14.68	13.81	8.12
Total	32 398 681	10 197 773	15 528 160	6 867 412	64 992 026

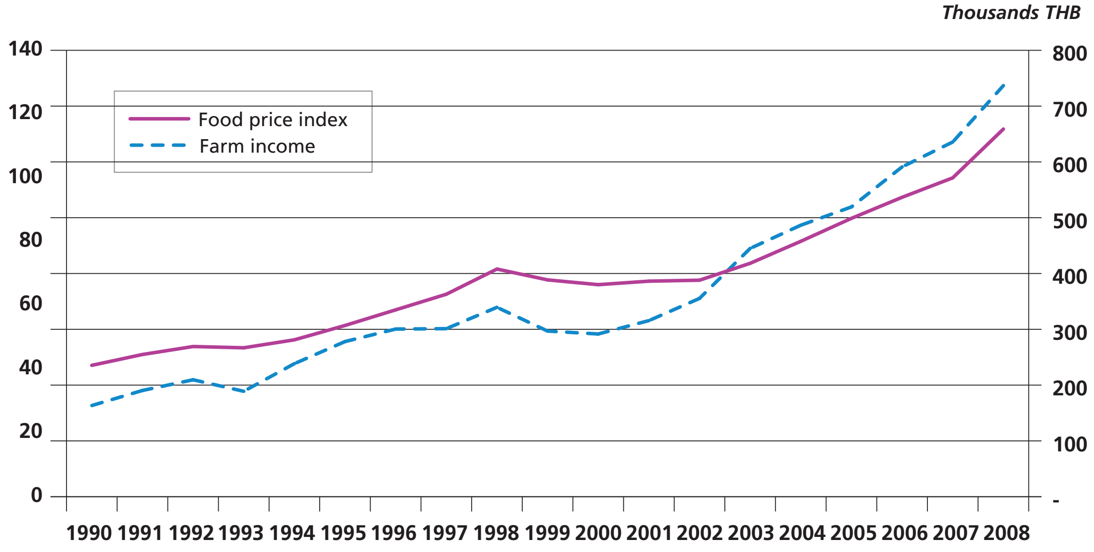
Source: NSO – calculated from 2009 Socio-Economic Survey.

As noted above, the food poverty line is the base amount of expenditure on food per person per month required to be considered out of poverty. Generally, for households with no farm income, growth in the food poverty line might cause them to fall into poverty if their total income is only marginally above the poverty line to begin with. However, the extent to which the food price changes affect the poverty situation of households with farm income depends on whether the increase in farm income compensates for the increase in the poverty line.

To estimate the potential impact of price increase on farm income it is first required establishing a link between food prices and farm income. As can be seen in Figure 8.4 the two variables are correlated.

FIGURE 8.4

Food price and farm income 1990-2008



Source: TDRI.

Formally, a simple function of farm income could be described as:

$\textit{Farm Income} = f(\textit{food price, agricultural production})$

Using linear regression estimation, the function can be described in logarithmic form as:

$\log(\textit{Farm Income}) = 1.17 * \log(\textit{food price}) + 0.62 * (\textit{agricultural GDP})$

Using annual data from 1993 to 2008, the two coefficients were estimated and they are significant at the 95 percent confidence level. The standard error for the food price coefficient (1.17) is ±0.1. These results mean that a one percent increase in the food price will lead to an increase in farm incomes ranging between 1.07 to 1.27 percent. This is the elasticity of the farm income to the food price.

Based on observed data, two cases were tested, namely one with elasticity of 1.10 and the other with elasticity of 1.25. For each case, three scenarios of possible food price increases were tested ranging from three to ten percent. Farm income per household is calculated by multiplying the relevant coefficient of either 1.10 or 1.25 by the percentage increase in food price. In all scenarios, the food poverty line increases by the same margin as the food price. The assumptions of all six scenarios are shown in Table 8.3.

TABLE 8.3

Scenario assumptions

Scenarios	Food price increase	Farm income increase	
		Elasticity = 1.10	Elasticity = 1.25
	%	%	%
S1	3.00	3.30	3.75
S2	5.00	5.50	6.25
S3	10.00	11.00	12.50

Source: TDRI.

These scenarios were applied to household data from the 2009 SES to assess how the various changes in food prices influence food poverty line and farm income by region and by household type. From Table 8.4 it can be seen that following a rise in food price poverty increases in all regions under the vast majority of scenarios tested. Interestingly, lower farm income elasticity leads to a larger overall increase in the poverty incidence. According to the results the South will see the greatest rise in poverty incidence followed by the Northeast. The likely reason for this is that the South may have a high number of households living just above the food poverty line. While the Northeast is home to the greatest number of poor households there may be less currently living just above the food poverty line than in the South. Bangkok and the Central region face the smallest increase in poverty incidence.

TABLE 8.4

Changes in poverty incidence by region

Region	Elasticity = 1.00			Elasticity = 1.25		
	S1	S2	S3	S1	S2	S3
Bangkok	0.00	0.07	0.30	0.00	0.07	0.30
Central	0.09	0.15	0.33	0.06	0.14	0.24
North	0.15	0.24	0.46	0.06	0.06	0.18
Northeast	0.23	0.39	0.91	0.15	0.28	0.49
South	0.24	0.42	1.03	0.16	0.33	0.79
Total	0.16	0.28	0.65	0.10	0.19	0.40

Source: TDRI.

When looking at the impact by type of household, rice only farmers are hit hardest by rising food prices under each scenario (Table 8.5). This could be because rice only households are generally closer to the food poverty line than the other household types considered. Interestingly, the incidence of poverty among non-agriculture households generally increases at a rate greater than the agricultural households not producing rice and the ones producing rice and other crops. In fact, under the second elasticity case, the incidence of poverty in these types of household grows at a much lesser rate than the other two household types and even declines for the household producing rice and other crops. This finding would seem to indicate that growth in farm income resulting from higher food prices may under certain scenarios offset the change in the food poverty line and lead to benefits for some households.

However, based on this analysis, in general an increase in food prices leads to greater incidence of poverty. This is because poorer households will still tend to spend a large proportion of their slightly greater income on now more expensive food products.

TABLE 8.5

Changes in poverty incidence by household type

Household Type	Elasticity = 1.00			Elasticity = 1.25		
	S1	S2	S3	S1	S2	S3
Non-agriculture	0.11	0.19	0.54	0.08	0.17	0.53
Agriculture – No rice	0.11	0.18	0.36	0.01	0.09	0.05
Agriculture – Rice only	0.31	0.58	1.14	0.23	0.43	0.66
Agriculture – Rice and other crop	0.17	0.16	0.46	0.04	-0.09	-0.31
Total	0.16	0.28	0.65	0.10	0.19	0.40

Source: TDRI.

8.2.2 Impact of biofuels on Thai economy

As discussed in Section 8.1.2, expanding the biofuel sector can also impact on households through the broader economy. Table 8.6 presents the outputs of the CGE model following a simulated expansion of the biofuels sector by increasing the price of food imports by one percent.

TABLE 8.6

Impact of one percent increase in import food price on economic growth and price levels

	Percent change from the base year
Overall GDP growth	-0.07
Agriculture sector	1.32
Industrial sector	-0.30
Service sector	-0.16
Price level	
Consumer index	0.47
GDP deflator	0.04

Source: TDRI.

Table 8.6 displays the impact in terms of economic growth and price levels. The agricultural sector clearly benefits from higher prices of imported food increasing production by 1.32 percent. However, industrial and service sectors suffer as they use agricultural products as inputs and increased prices for these products translate into increased production costs. General prices rise along with import prices. Consumer prices are more greatly affected than the GDP deflator because the consumer price index includes a higher proportion of food items than the GDP deflator.

TABLE 8.7

Impact of one percent increase in import food price on change in foreign trade

Foreign trade	Million THB	Percent change from the base year
Export of goods	0	0.00
Import of good	5 221	0.11
Trade account	-5 273	1.56
Current account	-2 143	0.71

Source: TDRI.

The effects on foreign trade are presented in Table 8.7. The level of exports remains unchanged as a change to exports is not assumed in the model. The value of imports increases following higher prices for food imports, which more than offset the decline in the amounts imported in other sectors as a result of lower GDP. As a result, both the trade and current accounts deficits are reduced as a result of higher imported food prices.

TABLE 8.8

Impact of one percent increase in import food price on change in real final demand

Final Demand and Components	Million THB	Percent change from the base year
Household consumption	-19 113	-0.47
Government consumption	-318	-0.04
Public investment	-2 403	-0.47
Private investment	-8 410	-0.47
Export of goods & services	876	0.02
Less import of goods & services	-24 302	-0.46
Total final demand	-5 065	-0.07

Source: TDRI.

Table 8.8 shows the effects on real final demand and its components. Except for exports, all other components of final demand decline.

TABLE 8.9

Impact of one percent increase in import food price on change in real household income

Household Groups	Base year million THB	After shock million THB	Change from the base year million THB	Change from the base year %
Farm 1 (the poorest)	13 500	13 494	-6	-0.04
Farm 2	28 974	28 982	8	0.03
Farm 3	37 302	37 347	45	0.12
Farm 4	38 622	38 681	59	0.15
Farm 5	48 319	48 398	79	0.16
Farm 6	52 207	52 325	118	0.23
Farm 7	61 123	61 306	183	0.30
Farm 8	68 058	68 306	248	0.36
Farm 9	72 033	72 374	340	0.47
Farm 10 (the richest)	202 072	203 592	1 520	0.75
Non-Farm 1 (the poorest)	9 372	9 219	-153	-1.63
Non-Farm 2	38 364	38 030	-333	-0.87
Non-Farm 3	71 089	70 498	-591	-0.83
Non-Farm 4	115 294	114 424	-869	-0.75
Non-Farm 5	154 391	153 287	-1 104	-0.72
Non-Farm 6	226 989	225 437	-1 552	-0.68
Non-Farm 7	326 855	324 704	-2 151	-0.66
Non-Farm 8	478 945	476 188	-2 756	-0.58
Non-Farm 9	733 914	730 219	-3 694	-0.50
Non-Farm 10 (the richest)	1 870 768	1 865 049	-5 719	-0.31
All Households	4 648 188	4 631 860	-16 327	-0.35

Source: TDRI.

Table 8.9 shows the effects on household incomes, where households are disaggregated into 20 groups by income class and by farm versus non-farm households. Most farm households, with the exception of the poorest, gain in terms of real income while all non-farm households experience reduced real income. The poorest farm households may show no gains in terms of real income because the share of food consumption among these households is higher compared to other groups. These results are generally consistent with those of the microeconomic analysis presented in Section 8.2.

8.2.3 Limitations of the micro and macro analysis

The analysis employed in this chapter suffers from a number of limitations that should be acknowledged before drawing any conclusions from the findings presented. Firstly, as noted in Section 1.1 due to the lack of appropriate data the analysis presented attempts to infer the possible impacts of an expansion of Thailand's biofuel sector by simulating a general increase in food prices. The analysis rests upon an assumption that an expansion of biofuel crop production will lead to a general rise in agricultural prices. This assumption neglects the possibility that expansion of biofuel crop production could lead to greater investment in domestic agriculture and improvement in agricultural yields. In the case that biofuel expansion leads to improved agricultural yields as anticipated by the AEDP, the effect of biofuel crop expansion could lead to increased output per level of inputs and reduced prices. Under this scenario the impact of the biofuel sector on poverty might be quite different to that which is discussed here.

In the macro level analysis, the use of a price shock to the import price level also raises some issues. While this method of analysis assisted in identifying how increases in food prices may affect households and the overall economy, it does not account for how the domestic economy may benefit from the establishment and expansion of the domestic biofuel sector. The expansion of the domestic biofuel sector should result in greater domestic output from both the agricultural and industrial sectors. However, the use of the import price as the instrument of change translates into increased output solely from the agricultural sector. Development of a CGE model with a specific biofuel sector may yield different results to those presented here.

Another element that is not considered is how the wider availability of biofuels could impact upon energy costs. As discussed in Chapter 6, expansion of biofuel production in line with the AEDP targets may result over time in the provision of a cheaper fuel source for Thai households and industry. Further analysis is required to address these limitations.

8.2.4 Small-scale bioenergy and rural development

Access to effective energy services is a basic requirement for social and economic development. Despite this fact, a considerable number of people in developing countries still rely on inefficient, traditional wood-based bioenergy for their basic energy requirements. In Thailand, 11 percent of primary energy supply is still sourced from traditional fuel wood.

As discussed in Chapter 1, the AEDP is not limited to the biofuel sector. A number of provisions under the AEDP aim to encourage a wide range of bioenergy developments including at the small, community scale. More effective sources of bioenergy may provide a diverse range of potential benefits to rural communities such as reduced time dedicated to sourcing fire wood and reduced risk of harmful smoke inhalation.

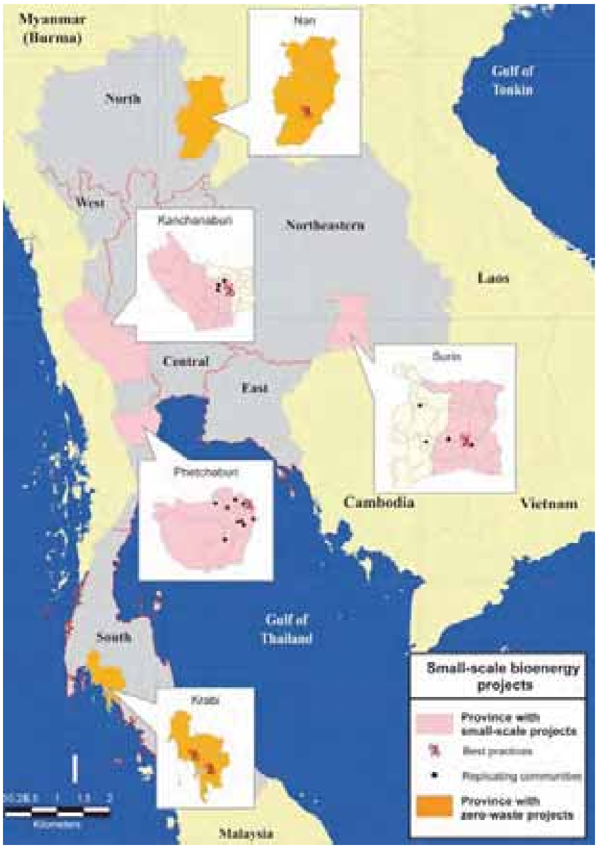
Unlike biofuels, which generally aim to provide an additional source of income for agriculture-based communities, small-scale bioenergy systems can allow rural communities to reduce energy expenditures and increase the value of otherwise discarded biomass wastes. In Thailand there is a wide-range of small-scale bioenergy systems employed by rural communities including biogas and small-scale biodiesel production. However, wide-spread adoption of successful technologies and initiatives has been relatively slow. Often attempts to replicate successful rural bioenergy projects fail due to absence of specific factors or conditions.

An assessment of these bioenergy technologies is important to understand how they could be used to reduce the energy expenditures of rural and poorer communities. Better documentation of these best practice rural bioenergy projects and the factors behind their success will also be crucial if new communities are going to be convinced to adopt a bioenergy project in the future.

For the purpose of the survey three best practice communities were identified along with 17 communities which have attempted to replicate their success in establishing a small-scale, community bioenergy project. The communities surveyed were located in three provinces encompassing a range of different technologies including biogas, biodiesel, high-efficiency charcoal kilns, thermal power generation and advanced wood stoves. Figure 8.5 shows the locations of the projects.

FIGURE 8.5

Location of small-scale bioenergy projects



The three best practice cases identified were Don Phing Dad in Phetchaburi province, Lao Khwan in Kanchanaburi province and Ta-Ong in Surin province.

8.2.4.1 Best practice case - Don Phing Dad

Of these three cases Don Phing Dad is considered the best example of successful implementation of a small-scale, community bioenergy project. It is a farming community in Petchaburi province in the Central region of Thailand on the cusp of the Southern provinces. In the last few years the heavy use of chemicals fertilizer has degraded the quality of local soils. Most of the people in the village do not own land.

In an effort to reverse growing degradation of local soils the community requested the assistance of the Research and Development Institute of Silpakorn University to adopt organic farming techniques. Together with the organic farming processes the Institute advocated the use of high-efficiency charcoal kilns and biodiesel production from waste cooking oil. The bioenergy operation that was subsequently adopted at Don Phing Dad involves a wide range of actors including 70 farmer households. The community now produces 1 500 litres of biodiesel and approximately 9 600 kg of high-efficiency charcoal per month.

The community has also established a training centre where people from surrounding communities can learn about the project implemented in Don Phing Dad and purchase the community's outputs of wood vinegar, biodiesel and charcoal. Wood vinegar is a by-product of the charring process that is used as a means of pest control instead of chemical pesticides. This centre has been recognised as a Ministry of Energy biodiesel learning centre and has received financial support from the Thai Government.

For the purpose of the survey nine communities were identified in Petchaburi province which had attempted to replicate the Don Phing Dad case. These communities consisted of mainly rice and fruit farmers. While most communities surveyed were supported by government funds, some relied on their own resources. It was found that the production of biodiesel in the replicating communities is very limited due to insufficient availability of waste cooking oil feedstock. However, these communities successfully produce high-efficiency charcoal and wood vinegar. Interestingly, the least successful cases identified limited financial support from government sources and lack of waste oil as key barriers to success.

In general the communities surveyed were satisfied with their attempts to replicate the Don Phing Dad case noting that their outputs of high-efficiency charcoal have reduced household expenditures on liquefied petroleum gas (LPG), improved their health and helped to restore the environment in their communities. Some farmers have also had some success in selling high-efficiency charcoal, wood vinegar and biodiesel products.

8.2.4.2 Best practice case – Lao Khwan

The Lao Khwan sub-district is located in Kanchanaburi province in the west of Thailand. In the past Lao Khwan suffered from low agricultural productivity and lack of collaboration between local farmers. In 2007 a group of farmers formed the Connecting Wisdom group. The group has four main activities, namely growing herbs, producing organic fertilizer, raising fish and generating biogas. The community installed a biogas digester at a cost of approximately $2 300 and now produces 336 m3 of gas per month.

In terms of generating bioenergy from biogas a key factor behind the success of the Lao Khwan case is that this sub-district has the largest number of cattle in Kanchanaburi province. Animal waste is the key input for the biogas plant. Like the community in Don Phing Dad, the community in Lao Khwan established a learning centre to educate other communities about the benefits of cooperation and bioenergy. The Connecting Wisdom group subsequently expanded its network to nearby sub-districts and neighbouring provinces.

While four communities are attempting to replicate the Lao Khwan model with government assistance, so far only one community is successfully producing a regular supply of biogas. However, the projects surveyed are still at an early stage of development.

8.2.4.3 Best practice case – Ta-Ong

The Ta-Ong sub-district consists of 16 villages, 1 800 household and 20 000 people and is located in Surin province in North Eastern Thailand. The majority of the population are farmers who live below the poverty line. Their main resource is livestock. In 2007 Ta-Ong sub-district was selected as one of 80 communities to be part of the Ministry of Energy's *sustainable energy communities* program. With the assistance of the North Eastern Thailand Development (NET) Foundation and the provincial energy office the community established biogas, high-efficiency charcoal, and energy efficient stove initiatives. The community now produces 108 m3 of biogas and 24 000 kg of high-efficiency charcoal per month. The community has since received a grant from Global Environment Facility (GEF) with the assistance of UNDP to expand biogas systems in the community to 80 units by 2010.

A number of communities from the surrounding area have approached the Ta-Ong community to replicate its biogas and high-efficiency charcoal facilities. At this stage, the technologies are mostly transferred through informal training. To date two communities have installed biogas facilities and small high-efficiency charcoal kilns with the support of the provincial energy office.

8.2.4.4 Financial analysis of zero-waste bioenergy projects

For the financial analysis of the zero-waste systems three cases were assessed:

- a jatropha-based system in Viengsa district in Nan province started in 2006;
- a rice-based system at Bankoh-klang village in Krabi province started in 2007; and
- a palm oil-based system at Huay young village in Krabi province started in 2008.

Key elements of these projects were the availability of strong community leadership, access to technical knowledge and finance – usually in the form of government grants and/or community savings. It was found that all of the projects assessed were financially unviable at this stage without some kind of external support. While the rice and oil palm systems were at an early stage of development, initial financial assessments indicate that these systems will be more viable than the jatropha-based system. The labour costs associated with the jatropha system were particularly high when compared to the revenue that could be generated from the sale of jatropha seed or biodiesel produced from crude jatropha oil.

However, one limitation of the analysis is that revenues from the sale of other by-products such as fertilizer and crafts could not be assessed due to a lack of data regarding market prices for these outputs. If a market for these by-products exists in the future and these communities are able to sell these products then the financial viability of these systems would improve dramatically. It should be noted that one important finding of the survey analysis is that successful rural bioenergy projects produce a range of outputs, which can be substituted for other commodities the communities would otherwise have to import such as LPG, pesticides and fertilizers. The ability to utilize and sell by-products appears to be a key determinant of the success and viability of small and community scale bioenergy projects.

Each community assessed for the financial analysis reported other benefits to the community associated with small-scale bioenergy operations such as self-sufficiency and improved cohesiveness within the community. This suggests that there may be other benefits derived from the implementation of small-scale systems that do not lend themselves to traditional financial analysis. It was determined that future assessments of these projects should attempt to monetize the external impacts of these operations to assess their true cost and/or benefit to rural communities.

In terms of government support, while initial financial support appears crucial for communities to establish small-scale bioenergy systems, it may not address challenges associated with long-term operation and system maintenance. Overcoming these challenges will require education and regular access to technical assistance.

8.3 CONCLUSIONS

- *Any increase in agricultural prices that arise from development of the biofuel industry could lead to increased incidence of poverty in Thailand*. Despite significant progress in reducing poverty in Thailand, pockets of poverty still exist in certain regions of the country. Increases in agricultural prices have the potential increase the incidence of poverty in Thailand; particularly in households that are living just above the poverty line or rely solely on the sale of rice crops for income. Policy makers should ensure that strategies are in place to assist poorer households cope with potential growth in agricultural prices arising from development f the biofuels sector.
- *Strategies that aim to locate biofuel feedstock producing opportunities in poorer communities could have a positive effect and reduce the incidence of poverty*. The analysis presented in Section 1.2 indicates that households which produce a wider range of agricultural products will benefit more from any increase in agricultural prices. Development of the biofuel sector may present opportunities to encourage more crop diversification amongst poorer households providing additional sources of income and potentially lifting some households out of poverty. For such a strategy to be effective government would need to ensure that farmers were afforded appropriate support to manage the transition into new biofuel feedstock crops.
- *Higher agricultural prices will lead to growth of the agriculture sector*. The CGE analysis shows that higher agricultural prices will lead to greater output from the agricultural sector. As the vast majority of Thailand's poor are engaged in the agricultural sector stimulating balanced development of the biofuel sector may lead to positive outcomes in terms of poverty reduction.
- *Further investigation and monitoring is required to understand the true impact of the biofuel sector on households and the Thai economy*. The findings presented in this chapter are the result of a partial analysis of what could occur if development of the biofuel sector were to lead to general growth in agricultural prices. The availability of better datasets and more comprehensive models will provide a clearer picture of the true impact of the biofuel sector on households and the potential for poverty reduction. However, the analysis presented this chapter presents a solid reference point for future investigation.
- *Small-scale community-based bioenergy projects could promote rural development if designed on a thorough analysis of the local context in terms of capacity and specific needs*. A portfolio of best practices should be illustrated to interested communities and support should be provided to identify the most suitable one, analysing closer the community's needs and potentials in order to ensure a long term sustainability of the project. Technical and financial support should be provided not only at the initial stage of the project implementation. Monitoring could help to evaluate if further assistance is required to make the project sustainable. Particular emphasis should be given to the development of robust markets for by-products derived from small-scale bioenergy projects to ensure their long-term viability.

8.4 REFERENCES

Anuchiworawong C. 2010. *Fiscal policy toward more equitable economy and society: the case of indirect tax*, a research paper submitted to the Research Thailand Fund (in Thai).

FAO. 2010. *Household level impacts of increasing food prices in Cambodia*, by Maltsoglou I., Dawe D. and Tasciotti L., Environment and Natural Resource Management Working Paper n. 37, Rome.

Somchai J. & Siamwalla A. 2009. *Economic shocks and vulnerable in Thailand: A case study of rising food and fuel prices*, a research paper submitted to the United Nations, January 2009.

TDRI. 2009. *Macroeconomic impacts of organic agriculture: A case study of Thailand*, a research in progress financed by the Asian Development Bank Institute.

FAO ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT SERIES

1. **Africover: Specifications for geometry and cartography, summary report of the workshop on Africover, 2000 (E)**
2. **Terrestrial Carbon Observation: the Ottawa assessment of requirements, status and next steps, 2002 (E)**
3. **Terrestrial Carbon Observation: the Rio de Janeiro recommendations for terrestrial and atmospheric measurements, 2002 (E)**
4. **Organic agriculture: Environment and food security, 2002 (E, S)**
5. **Terrestrial Carbon Observation: the Frascati report on in situ carbon data and information, 2002 (E)**
6. **The Clean Development Mechanism: Implications for energy and sustainable agriculture and rural development projects, 2003 (E)***
7. **The application of a spatial regression model to the analysis and mapping of poverty, 2003 (E)**
8. **Land Cover Classification System (LCCS) + CD-ROM, version 2, Geo-spatial Data and Information, 2005 (E)**
9. **Coastal GTOS. Strategic design and phase 1 implementation plan, 2005 (E)**
10. **Frost Protection: fundamentals, practice and economics- Volume I and II + CD, Assessment and Monitoring, 2005 (E), 2009 (S)**
11. **Mapping biophysical factors that influence agricultural production and rural vulnerability, 2006 (E)**
12. **Rapid Agriculture Disaster Assessment Routine (RADAR), 2008 (E)**
13. **Disaster risk management systems analysis: a guide book, 2008 (E, S)**
14. **Community based adaptation in action: a case study from Bangladesh, 2008 (E)**
15. **Coping with a changing climate: considerations for adaptation and mitigation in agriculture, 2009 (E)**

Availability: August 2010

Ar	Arabic	**F**	French	**Multil**	Multilingual
C	Chinese	**P**	Portuguese	*	Out of print
E	English	**S**	Spanish	**	In preparation

The FAO Technical Papers
are available through the authorized
FAO Sales Agents or directly from:

Sales and Marketing Group - FAO
Viale delle Terme di Caracalla
00153 Rome - Italy

FAO ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

1. Inventory and monitoring of shrimp farms in Sri Lanka by ERS SAR data, 1999 (E)
2. Solar photovoltaic for sustainable agriculture and rural development, 2000 (E)
3. Energía solar fotovoltaica para la agricultura y el desarrollo rural sostenibles, 2000 (S)
4. The energy and agriculture nexus, 2000 (E)
5. World wide agroclimatic database, FAOCLIM CD-ROM v. 2.01, 2001 (E)
6. Preparation of a land cover database of Bulgaria through remote sensing and GIS, 2001 (E)
7. GIS and spatial analysis for poverty and food insecurity, 2002 (E)
8. Environmental monitoring and natural resources management for food security and sustainable development, CD-ROM, 2002 (E)
9. Local climate estimator, LocClim 1.0 CD-ROM, 2002 (E)
10. Toward a GIS-based analysis of mountain environments and populations, 2003 (E)
11. TERRASTAT: Global land resources GIS models and databases for poverty and food insecurity mapping, CD-ROM, 2003 (E)
12. FAO & climate change, CD-ROM, 2003 (E)
13. Groundwater search by remote sensing, a methodological approach, 2003 (E)
14. Geo-information for agriculture development. A selection of applications, 2003 (E)
15. Guidelines for establishing audits of agricultural-environmental hotspots, 2003 (E)
16. Integrated natural resources management to enhance food security. The case for community-based approaches in Ethiopia, 2003 (E)
17. Towards sustainable agriculture and rural development in the Ethiopian highlands. Proceedings of the technical workshop on improving the natural resources base of rural well-being, 2004 (E)
18. The scope of organic agriculture, sustainable forest management and ecoforestry in protected area management, 2004 (E)
19. An inventory and comparison of globally consistent geospatial databases and libraries, 2005 (E)
20. New LocClim, Local Climate Estimator CD-ROM, 2005 (E)
21. AgroMet Shell: a toolbox for agrometeorological crop monitoring and forecasting CD-ROM (E)**
22. Agriculture atlas of the Union of Myanmar (agriculture year 2001-2002), 2005 (E)
23. Better understanding livelihood strategies and poverty through the mapping of livelihood assets: a pilot study in Kenya, 2005 (E)
24. Mapping global urban and rural population distributions, 2005 (E)
25. A geospatial framework for the analysis of poverty and environment links, 2006 (E)
26. Food Insecurity, Poverty and Environment Global GIS Database (FGGD) and Digital Atlas for the Year 2000, 2006 (E)
27. Wood-energy supply/demand scenarios in the context of the poverty mapping, 2006 (E)
28. Policies, institutions and markets shaping biofuel expansion: the case of ethanol and biodiesel in Brazil, (E)**
29. Geoinformation in socio-economic development determination of fundamental datasets for Africa, (E, F)**
30. Assessment of energy and greenhouse gas inventories of sweet sorghum for first and second generation ethanol, 2009 (E)
31. Small-scale Bioenergy Initiatives: brief description and preliminary lessons on livelihood impacts from case studies in Asia, Latin America and Africa, 2009 (E)
32. Review of Evidence on Dryland Pastoral Systems and Climate Change: Implications and opportunities for mitigation and adaptation, 2009 (E)
33. Algae Based Biofuels: A Review of Challenges and Opportunities for Developing Countries, 2009 (E)
34. Carbon finance possibilities for agriculture, forestry and other land use projects in a smallholder context, 2010 (E, F, S)
35. Bioenergy and Food Security: the BEFS analysis for Tanzania, 2010 (E)

36. **Technical Compendium: description of agricultural trade policies in Peru, Tanzania and Thailand, 2010 (E)**
37. **Household level impacts of increasing food prices in Cambodia, 2010 (E)**
38. **Agricultural based livelihood systems in drylands in the context of climate change: inventory of adaptation practices and technologies of Ethiopia (E)****
39. **Bioenergy and Food Security: The BEFS Analysis for Peru, Technical Compendium Volume 1: Results and Conclusions; Volume 2: Methodologies, 2010 (S)**
40. **Bioenergy and Food Security: The BEFS Analysis for Peru, Supporting the policy machinery in Peru, 2010 (E, S)**
41. **Analysis of climate change and variability risks in the smallholder sector: case studies of the Laikipia and Narok districts representing major agro ecological zones in Kenya, 2010 (E)**
42. **Bioenergy and Food Security: the BEFS analysis for Thailand, 2010 (E)**

Availability: June 2006

Ar	Arabic	**F**	French	**Multil**	Multilingual
C	Chinese	**P**	Portuguese	*	Out of print
E	English	**S**	Spanish	**	In preparation

ENVIRONMENT – CLIMATE CHANGE – BIOENERGY – MONITORING AND ASSESSMENT
FAO - ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

The FAO Technical Papers
are available through the authorized
FAO Sales Agents or directly from:

Sales and Marketing Group - FAO
Viale delle Terme di Caracalla
00100 Rome - Italy


ENVIRONMENT – CLIMATE CHANGE – BIOENERGY – MONITORING AND ASSESSMENT
FAO - ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

The Government of Thailand, through its Alternative Energy Development Plan, has set a target of increasing its biofuels production to five billion litres by 2022. The Thai Government sees this expansion as a way to strengthen the country's energy security, foster rural development and reduce greenhouse gas emissions. In recent years, due to a broad global interest in bioenergy development, FAO set up the Bioenergy and Food Security (BEFS) project to support countries to make informed decisions in order to limit the risks of hindering food security, and at the same time to increase their opportunity to improve the lot of the most vulnerable and underprivileged part of society.

The analysis presented in this document is the result of the implementation of the BEFS Analytical Framework in Thailand. The framework envisages analyzing the effects of the bioenergy sector on the agricultural market and the use of natural resources, it evaluates the economic competitiveness and the effects on greenhouse gas emissions, and finally, it highlights the socio-economic aspects of bioenergy development.

The main findings and recommendations for policy-makers to develop the biofuel sector without impacting food security are being published in "*BEFS Thailand - Key results and policy recommendations for future bioenergy development*".

Climate, Energy and Tenure Division (NRC) publications
Series: www.fao.org/climatechange/61878
Working papers: www.fao.org/climatechange/61879

NRC contact: NRC-Director@fao.org

Food and Agriculture Organization of the United Nations (FAO)
www.fao.org

ISBN 978-92-5-106644-7 ISSN 2071-0992
I1739E/1/08.10