ISSN 2071 - 0992

42

Bioenergy and Food Security

The BEFS analysis for Thailand



ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT CLIMATE CHANGE [BIOENERGY] MONITORING AND ASSESSMENT

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Environment and Natural Resources series design: studio@bartoleschi.com, 2004

FAO - ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT – CLIMATE CHANGE – BIOENERGY – MONITORING AND ASSESSMENT

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Bioenergy and Food Security

The BEFS analysis for Thailand

Mirella Salvatore
Beau Damen

BEFS
Bioenergy and Food Security Project

Food and Agriculture Organization of the United Nations, Rome 2010

ISBN 978-92-5-106644-7

FOREWORD

In an effort to improve energy access, energy security and to lower global green house gas emissions, many countries have placed bioenergy developments high on their agenda. Over time, however, serious concerns about the effect of bioenergy on food security, its social feasibility and level of sustainability have arisen, especially with first generation bioenergy. In this context FAO, with generous funding from the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), set up the Bioenergy and Food Security (BEFS) project to assess how bioenergy developments could be implemented without hindering food security.

During its term, the BEFS project has supported Peru, Tanzania and Thailand in assessing the feasibility of the bioenergy sector, potential impacts on food security, growth and poverty. In this effort, BEFS has constructed an analytical framework that can assist countries with the development of bioenergy policy and/or clarification of the potential impacts of bioenergy developments.

The analysis presented in this document describes the implementation of the BEFS Analytical Framework in Thailand. The results of the analysis formed the basis for the policy discussion with the Thai Government during the *BEFS Thailand Policy Consultation* in June 2010.

The main findings and recommendations for policy-makers how to achieve the envisaged biofuel targets in a sustainable way without impacting food security are being published in a separate volume entitled "*BEFS Thailand – Key results and policy recommendations for future bioenergy development*".

As part of its activities, BEFS has also run training programmes in the participating countries to ensure full ownership, replicability and potential extensions to the analysis presented.

Heiner Thofern
Senior Natural Resources Management Officer
BEFS Project Coordinator

ABSTRACT

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 the 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 at the macro and micro level.

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

Bioenergy and Food Security: the BEFS analysis for Thailand
by Mirella Salvatore and Beau Damen

107 pages, 40 figures and 45 tables.

Environment and Natural Resources Working Paper No. 42 - FAO, Rome, 2010.

Keywords:
Bioenergy, food security, rural development, Thailand, BEFS.

This series replaces the following:
Environment and Energy Series
Remote Sensing Centre Series
Agrometeorology Working Paper

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ACKNOWLEDGEMENTS

A very large number of experts have assisted in the work reported in this publication. First of all we would like to thank the BEFS Thailand Technical Partners for their technical contribution in specific chapters of this document:

- Chapter 3: Dr Jirapa Inthisang, Ms Tapee Vatcharangkool and Ms Orapim Sundaraketu, Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives, with the technical training, support and supervision of Holger Matthey, Trade and Markets Division of FAO;
- Chapter 4: Mr Yuttachai Anuluxtipun, Land Development Department (LDD), Ministry of Agriculture and Cooperatives;
- Chapter 5: Mr Upali Amarasinghe, International Water Management Institute (IWMI);
- Chapter 6 and 7: Mr Werner Siemers, Dr Boonrod Sujjakulnukij and Mr Nattapong Chayawatto, Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi;
- Chapter 8: Dr Somchai Jitsuchon, Thailand Development Research Institute (TDRI); Dr Apichai Puntasen, Rural and Social Management Institute (RASMI); Mr Thanapon Sreshthaputra, ChangeFusion Institute; and Prof Sombat Chinawong, Krabi Campus Establishment Project, Kasetsart University.

Within to all the BEFS Thailand Policy Counterpart, we would like to thank the following for useful insights and comments in the preparation of this document:

- Mr Montree Boonpanit and Dr Suppatra Cherdchuchai, National Economic and Social Development Board (NESDB);
- Dr Twarath Sutabutr, Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy;
- Dr Shabbir Gheewala, JGSSE.

The BEFS Thailand project benefited from the overall support of Mr Hiroyuki Konuma and from collaboration with experts of the Regional Office for Asia and Pacific. A special thank to Mr Sverre Tvinnereim, Ms Suntaree Rangkusone, Ms Delgermaa Chuluunbaatar, Mr Ruben van der Laan, Mr Patrick Durst, Mr Simmathiri Appanah, Mr Sumiter Brocha, Mr Thierry Facon and Mr Yuji Niino.

In FAO Headquarters we would like to thank Heiner Thofern and Andreas von Brandt, for their managerial support.

Claudia Tonini provided valuable assistance with graphic design and formatting and Jeannie Marshall with editing.

This study was undertaken in the framework of the Bioenergy and Food Security project (GCP/INT/020/GER) with funding from the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV).

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ACRONYMS

ADB	Asian Development Bank
AEDP	Alternative Energy Development Plan
AFTA	ASEAN Free Trade Area
ASEAN	Association of South-East Asian Nations
B2	Biodiesel blending target at 2 percent
B5	Biodiesel blending target at 5 percent
BAAC	Bank of Agriculture and Agricultural Cooperatives
BEFS	Bioenergy and Food Security
BHD	Bio-hydrogenated diesel
CDM	Clean Development Mechanism
CGE	Computable General Equilibrium
COSIMO	Commodity Simulation Model
CPI	Consumer producer price
CPO	Crude palm oil
DEDE	Department of Alternative Energy Development and Efficiency
EIA	Energy Information Administration
ENCON	Energy Conservation Promotion
EPPO	Energy Policy and Planning Office
EU	European Union
FAO	Food and Agriculture Organization
FFB	Fresh fruit bunch
FTA	Free Trade Area
GDP	Gross Domestic Product
GEMIS	Global Emission Model for Integrated Systems
GEF	Global Environment Facility
GHG	Green House Gas
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return
JGSEE	Joint Graduate School of Energy and Environment
LCA	Life Cycle Analysis
LDD	Land Development Department
LEF	Low efficiency fossil
LPG	Liquefied petroleum gas
LRA	Logistic Regression Analysis
LSA	Land Suitability Assessment
LUC	Land use change
LUT	Land utilization type
MDG	Millennium Development Goal
MEF	Medium efficiency fossil
MOAC	Ministry of Agriculture and Cooperatives
MoE	Ministry of Energy
NAEO	National Alternative Energy Office

NESDB	National Economic and Social Development Board
NET	North Eastern Thailand Development Foundation
NPV	Net present value
NSO	National Statistical Office
OAE	Office of Agricultural Economics
OECD	Organization of Economic Cooperation and Development
OCSB	Office of the Cane and Sugar Board
RASMI	Rural and Social Management Institute
RE	Renewable energy
R&D	Research and Development
SES	Socio-Economic Survey
TDRI	Thailand Development Research Institute
TRWR	Total renewable water resource
TSM_SIMFARM	Thai Soil Management Simulation Farming
UN	United Nations
UNDP	United Nation Development Programme
WF	Water footprint
WTO	World Trade Organization

UNIT OF MEASURES

$	United States dollar
g	Gram
ha	Hectare
kg	Kilogram
ktoe	Kilotonne of oil equivalent
L	Litre
m^3	Meter cubic
mg	Milligram
MJ	megajoule
MLPD	Million litre per day
MLPY	Million litre per year
mm	Millimetre
MW	Megawatt
THB	Thailand bath (local currency unit)
ton	Tonne

CHAPTER 1

INTRODUCTION

As concerns about global greenhouse gas emissions and a desire for clean energy sources mount, many countries are exploring bioenergy developments as a possible solution. The Food and Agriculture Organization (FAO) of the United Nations has set up the Bioenergy and Food Security (BEFS) project to assess how bioenergy developments can be implemented without hindering food security.

Thailand has a rapidly developing biofuels sector. As Thailand has traditionally benefited from a robust agricultural sector, biofuels present new opportunities for Thai farmers who have long been able to produce enough food to feed the country and plenty more for export and other uses. With its Alternative Energy Development Plan (AEDP), the Thai Government aims to leverage its strong agricultural sector to expand biofuels production six-fold to five billion litres by 2022.

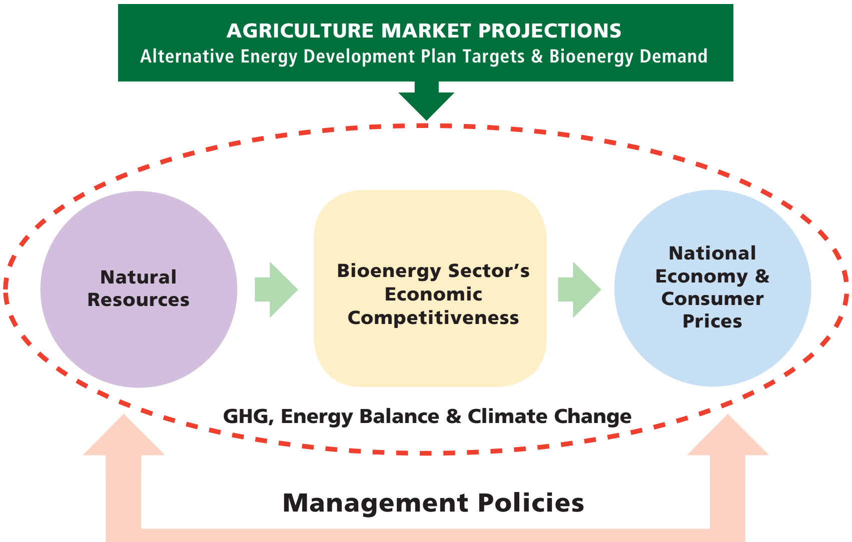
There are strong arguments for promoting biofuels and the Thai Government cites a number of them as justification for implementation of the AEDP including enhanced fuel energy security, reduced greenhouse gas emissions and new opportunities for rural development. But there are also potential risks associated with expanding biofuel production to the scale anticipated by the AEDP. Biofuel production systems compete with food production for land and agricultural resources which can potentially jeopardize food security. The precise impact on food security depends on a range of factors including the land used for bioenergy production, feedstock, agricultural management practices, the industrial set-up of the sector and developments in global agricultural and energy markets.

In the case of Thailand the key crops for biofuel production are sugar cane, cassava and oil palm. In some instances the Thai Government is anticipating that the effect of the AEDP on the production of these crops will be considerable. For example, between 2010 and 2022, cassava production is expected to increase from 2.27 million tons to more than 15 million tons, while crude palm oil output is expected double from 1.8 million tons to 3.4 million tons.

Ultimately, the long-term sustainability of the biofuels sector in Thailand depends on careful management of the country's natural resources. With the BEFS project, FAO has worked with Thai technical organizations to provide the knowledge and analysis to help guide future decisions regarding the expansion of the biofuels sector and management of the necessary natural resources. Essentially FAO wants to strengthen the capacity of the Thai Government to balance the trade-offs associated with the AEDP including potential risks to food security.

The BEFS analysis, as illustrated in Figure 1.1, is underpinned by the AEDP. The AEDP targets will affect Thailand's future agricultural market and will involve increased use of Thailand's natural resources. The efficiency of the Thai bioenergy sector in managing these resources will determine the economic competitiveness of the sector and its effect on climate. The sector will affect the national economy and households through the price of food made from the biofuel feedstock crops and from the price of biofuels, but also through a presumed increase in returns for farmers. The future sustainability of biofuels and bioenergy as alternative energy sources will depend on how the Thai Government manages the pressures that the bioenergy sector will place on its natural resources and agricultural markets.

FIGURE 1.1
BEFS Analytical Framework in Thailand



The BEFS analysis in Thailand does not only assess the feasibility of the bioenergy sector per se, but rather recognizes that biofuels and, to a large extent, bioenergy development is an extension of the agricultural sector. While the findings of the BEFS analysis indicate that Thailand is capable of meeting its ambitious targets, strategies will be necessary to improve agricultural productivity. Farming communities in Thailand will need more support if they are to bring about such improvements in productivity. Most of this investment will need to be directed toward Thailand's north and north-east regions, which, while the areas with the most potential for future expansion of cassava and oil palm production, are also home to most of Thailand's remaining poor.

But overcoming this challenge could unlock multiple dividends for Thailand. More productive farms, investment and improved farming techniques will increase farmers' incomes and reduce GHG emissions per unit of transport fuel produced. Greater income for Thailand's farmers will also have flow-on benefits to rural communities that will aid in continuing Thailand's progress over the past 20 years in reducing poverty and increasing food security.

The BEFS analysis for Thailand is structured as follows:

Chapter 2 sets the context against which the bioenergy sector is developed in Thailand. This section illustrates the macroeconomic performance of the country, the agriculture and energy sector, the socio-economic conditions, poverty, rural development and environmental issues. It also presents the status of bioenergy policy in Thailand.

Chapters 3 to 8 are the technical chapters of the analysis that contain the results of the main analytical components that constitute the BEFS Analytical Framework.

The main findings are then recapped in a separate volume entitled "BEFS Thailand - Key results and policy recommendations for future bioenergy development". The results are used to provide information and recommendations for policy-makers how to achieve the envisaged biofuel targets in a sustainable way without impacting food security.

CHAPTER 2

THAILAND CONTEXT

Thailand occupies the western half of the Indochinese peninsula and the northern two-thirds of the Malay Peninsula in Southeast Asia. It is delimited by Myanmar (Burma) to the west, Laos to the north and east, Cambodia to the southeast, and Malaysia to the south.

The National Research Council divides Thailand into six geographical regions, based on natural features including landforms and drainage, and into human cultural patterns. These divisions provide a clear basis for economic, social and ecological discussions. The northern region is mountainous and was traditionally the most heavily forested area of the country. The north-eastern region (Isarn) constitutes approximately one-third of the area of the Kingdom and almost one third of the population of Thailand lives in this region. The central region (including Bangkok Metropolitan Region) includes the basin of the Chao Phrya river which runs from north to south and, after crossing Bangkok, flows to the Gulf of Thailand. The geography of the western region of Thailand bordering with Myanmar, like the North, is characterized by high mountains and steep river valleys. The region hosts much of Thailand's less-disturbed forest areas. Water and minerals are also important natural resources; the region is home to many of the country's major dams, and mining is an important industry in the area. The eastern region, which comprises the hilly countryside from Bangkok to the Cambodian border, is characterized by higher rainfall and poorer soils than the adjoining central region. It is an important area for growing fruit, maize and cassava, and its coastline offers extensive opportunities for fisheries and tourism. The southern region, part of a narrow peninsula, is distinctive in climate, terrain and resources, and is the principal rubber-growing area. The forests of the south, as elsewhere in the Kingdom, have been seriously overcut. In recent years, the region has suffered from severe flooding, which is worsening because of deforestation and the subsequent soil erosion.

The Thai economy is one of the most robust in Asia. In the 1960s, the economy was predominantly based on agriculture and largely dependent on its abundant produce such as rice, cassava, maize, rubber and sugar cane, along with its production of seafood, primarily shrimp. In that period, Thai GDP depended heavily on the agriculture sector (37 percent of GDP) and the majority (more than 80 percent) of the labour force worked in the sector. The 1980s to mid-1990s marked the boom years in Thailand and saw the country develop into a diverse, modern and industrialized economy. Thailand used its strong agricultural sector to initiate a shift into industrialization. The availability of cheap local labour, enabled the country to shift into manufacturing and processing products for export purposes, starting with simple agri-based manufacturing and steadily progressing to more sophisticated industries. This led to the rapid expansion of the manufacturing sector and a marked increase in exports. Since this time the contribution of the agriculture sector to Thailand's GDP has declined. In 2008 agriculture accounted for less than nine percent of GDP, while services and industry made up around 45 percent each.

Thailand's real GDP growth in 2008 was 2.6 percent, falling below previous Thai Ministry of Finance growth estimates due to the emerging global economic crisis. Falling global demand associated with the onset of the crisis put particular pressure of Thailand's export sector, which accounts for around 60 percent of GDP

– a trend that continued into 2009. During the first quarter of 2009, total exports declined by 23.1 percent year-on-year, which contributed to a 7.1 percent contraction in total GDP. Headline inflation in January 2009 was -0.4 percent. The Thai Government adopted a two-stage fiscal stimulus response to address the effects of the crisis. The first phase, introduced in February 2009, was aimed at stimulating domestic purchasing power through cash handouts. The second phase, worth around US $57 billion, will be implemented over the 2010-12 period and is targeted at stimulating a range of large scale infrastructure projects.

Thailand is a member of the World Trade Organization (WTO) and the Cairns Group of agricultural exporters. Thailand is also part of the ASEAN Free Trade Area (AFTA). Thailand has actively pursued free trade agreements with: China commencing in October 2003, but limited to agricultural products, with a more comprehensive FTA to be agreed upon by 2010; India in 2003 when it began a limited agreement; Australia in January 2005 when it commenced a full agreement; and, Japan in February 2004 when Thailand began free trade negotiations, and in September 2005 when they made an in-principle agreement. Negotiations for a USA-Thailand Free Trade Agreement began in 2004 but were suspended in 2006 following the dissolution of the Thai Parliament and the subsequent military-led coup. The United States and Thailand held informal consultations and had a formal dialogue on trade and investment issues in June 2008, and held informal meetings in March 2009.

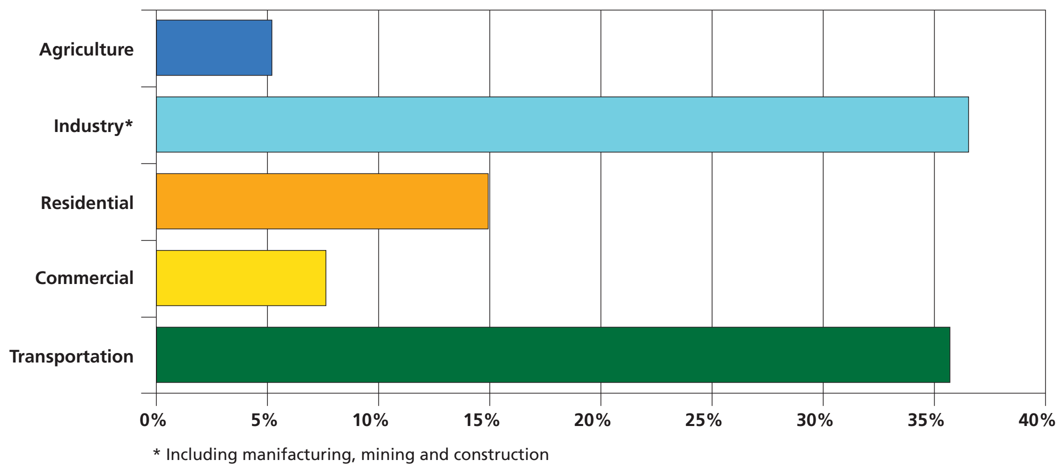
2.1 THE ENERGY SECTOR

Thailand's energy consumption has remarkably increased at pace with the recovery that began after the 1997 economic crisis. Thailand's strong economic performance since this time is reflected in the increasing growth of industrial output and energy consumption.

According to preliminary data provided by the Department of Alternative Energy Development and Efficiency (DEDE) of the Ministry of Energy (MoE), in 2009 the industrial and transport sectors were the largest consumers of energy accounting for 36.6 percent and 35.7 percent of final energy consumption respectively. In contrast, the agriculture sector accounted for only 5.2 percent of final energy consumption (Figure 2.1). These shares have remained relatively constant over the past five years.

FIGURE 2.1

Final energy consumption by economic sector in 2009



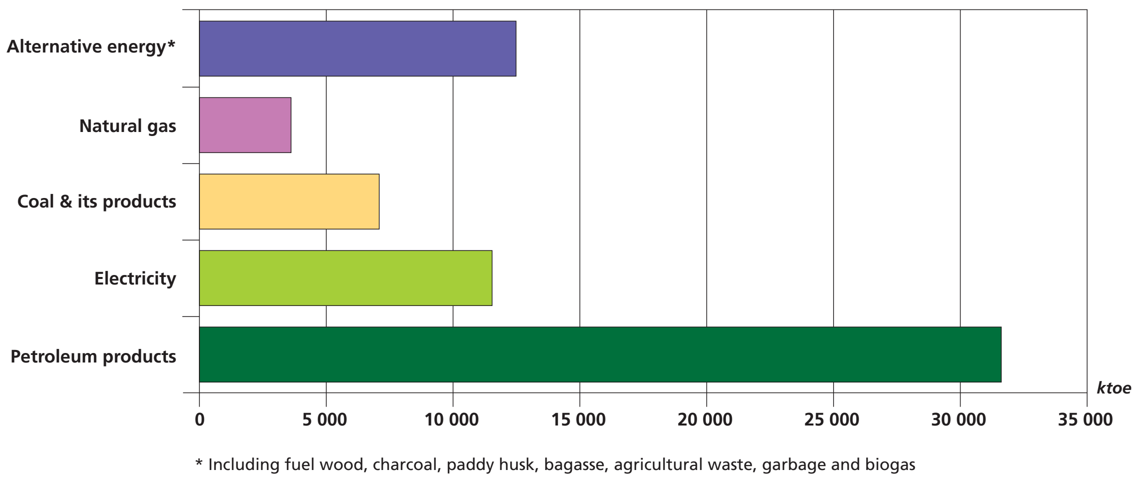
Source: DEDE.

In 2009, commercial energy, which consists of petroleum products, natural gas, coal, lignite and hydro, accounted for 66.5 percent of total energy produced and 80.6 percent of energy consumed. Renewable energy, which consists of fuel wood, paddy husk, bagasse, agricultural and municipal waste, biogas, solar, wind and geothermal accounted for 31.8 total domestic energy production and 18.4 percent of energy consumed. Biofuels accounted for 1.3 percent of total energy production and 0.8 percent of domestic energy consumption.

Over the past five years the commercial energy sector's share of domestic primary energy production has fallen slightly due to small increases in use of agricultural wastes, biofuels and biogas as energy sources. However, as indicated above, in terms of consumption Thailand is still largely dependent on fossil fuels to power its economy. To meet continued growth for energy Thailand has expanded domestic production of energy and supplement domestic supplies with imports. In the last two decades, Thailand has increased its production of crude oil more than seven fold while production of natural gas has increased more than five fold. Interestingly, the next largest domestically produced energy source is fuel wood. Figure 2.2 presents final energy consumption by fuel type in 2009. While natural gas is the main locally produced energy source it still only accounts for 5.4 percent of final energy consumption.

FIGURE 2.2

Final energy consumption by type in 2009



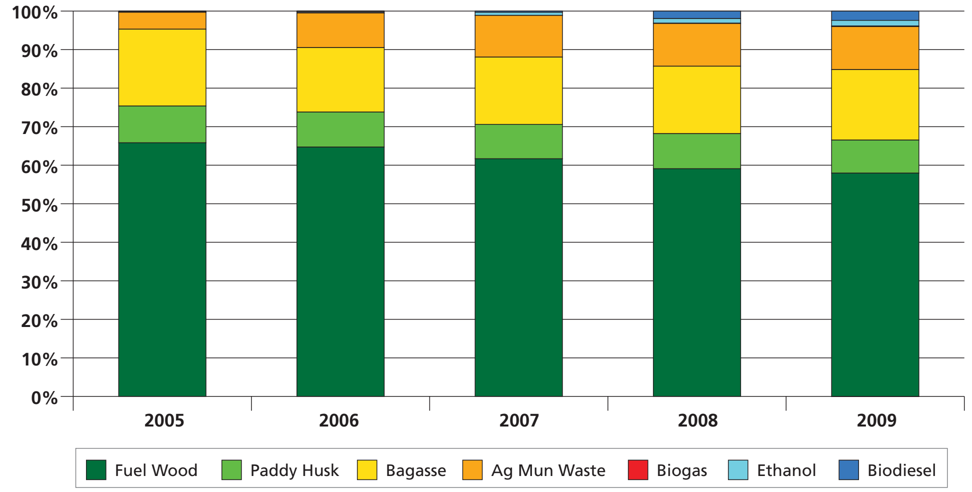
Source: DEDE.

In terms of exposure to international energy markets, practically all of Thailand's energy imports are from commercial fossil energy sources with crude oil accounting for the vast majority. National policies aimed at reducing oil imports through energy efficiency measures and increased domestic energy production have aided to reduce energy imports over the past decade – particularly of petroleum products. However, the reduction in consumption of petroleum products has been relatively small and has not been matched by a corresponding decrease in expenditures on energy imports. In fact, expenditures on energy imports have grown dramatically. For example, between 2002 and 2006 the value of crude oil imports increased from $6.67 billion to $19.77 billion, which was equivalent to 200 percent increase expenditure over the course of just five years. Since this time the global oil market has been characterized by ever increasing volatility.

While renewable energy is a domestically produced source of energy that already constitutes a large share of total final energy production and consumption in Thailand, inefficient fuel wood sources still constitute the largest share (Figure 2.3). Despite the perceived benefits of more efficient modern renewable energy systems, there are still a number of obstacles in the way of mainstreaming these new energy technologies including lack of consumer confidence and higher costs when compared to prevailing commercial energy sources. However, Thailand is particularly well placed to take advantage of new developments in the renewable energy sector; particularly with regard to bioenergy.

FIGURE 2.3

Alternative and renewable energy mix



Source: DEDE.

Thailand is traditionally an agriculture-based society. It currently produces a wide range of agricultural crops such as rice, sugar cane, rubber sheets, palm oil and cassava. Part of the harvest is exported each year, generating billions of baht revenues for the country. In processing these agricultural products, a large amount of residues are also generated. Some of these residues have been used as energy sources for industry; particularly in the agricultural processing sector. For instance, rice mills burn paddy husks to produce steam to power electricity generators, sugar mills and ethanol plants use bagasse to co-fire refinery operations, and palm oil refineries use residues to produce steam and electricity. Private industry is also developing biogas technology generated from animal manure and landfill for power generation and waste management purposes.

The major financial resource for these activities is the Energy Conservation Promotion Fund (ENCON Fund) established by the government under the Energy Conservation Promotion Act in 1992 to provide financial support to government agencies, state enterprises, non-government organizations, individuals and businesses that wish to implement measures to increase energy efficiency. Several biogas projects have been supported by the ENCON Fund, such as biogas from animal manure for generating power on livestock farms, and R&D on the feasibility of generating biogas from wastewater treatment.

The Thai biofuel sector is relatively small but developing rapidly. The key biofuel crops are sugar cane (molasses) and cassava for ethanol and palm oil for biodiesel. However, other feedstocks are used to produce biodiesel such as waste cooking oil and stearine, which is a by-product from refining palm oil.

The production of ethanol for transport purposes in existing alcohol refineries and sugar milling operations began in 2004. Since this time the number of ethanol refineries has expanded with total production capacity now at 2.575 million litres per day (MLPD) or 940 million litres per year (MLPY). Actual ethanol demand is around one MLPD meaning that there is currently excess production capacity. Thai Government policies aimed at expanding the market for ethanol have encouraged new entrants into the ethanol sector with a number of refineries planned or under construction. However, unlike existing facilities most new production facilities are expected to use cassava as their key feedstock. Once these facilities are complete, it is expected production capacity will increase to 3.24 MLPD or 1 180 MLPY.

Large-scale biodiesel production for blending into fossil diesel began in 2007. In 2008 biodiesel consumption increased to 1.2 MLPD (438 MLPY) and around two MLPD (730 MLPY) in 2009. Refineries planned or under construction are expected to bring total production capacity to 4.5 MLPD or 1 640 MLPY. Large-scale biodiesel refineries are concentrated in the south of Thailand near oil palm plantations and around Bangkok near fossil fuel refineries and fuel distributors. Biodiesel production at small-scale facilities is currently not included in national statistics, but is thought to be minimal.

2.1.1 The Alternative Energy Development Plan

Thailand's policy framework for bioenergy and biofuels is underpinned by the Alternative Energy Development Plan, which will be implemented over the period from 2008 to 2022. The plan has three phases (short-term 2008 to 2011, medium-term 2012 to 2016 and long-term 2017 to 2022) and aims to increase the share of Thailand's energy supply delivered by alternative energy sources to 20.3 percent by the final year of implementation. DEDE is the Thai Government agency responsible for implementing the AEDP.

The objectives of the AEDP are to:

- use alternative energy as the main source of energy, thus replacing oil imports;
- increase the country's energy security;
- promote the use of integrated green energy communities;
- enhance alternative energy technology industry development; and
- research, develop and encourage high efficiency alternative energy technologies.

The AEDP's three phases are:

Short term (2008–2011). During this phase DEDE will focus on promoting commercial alternative energy technologies and energy sources with high commercial potential such as biofuels, co-generation from biomass and biogas.

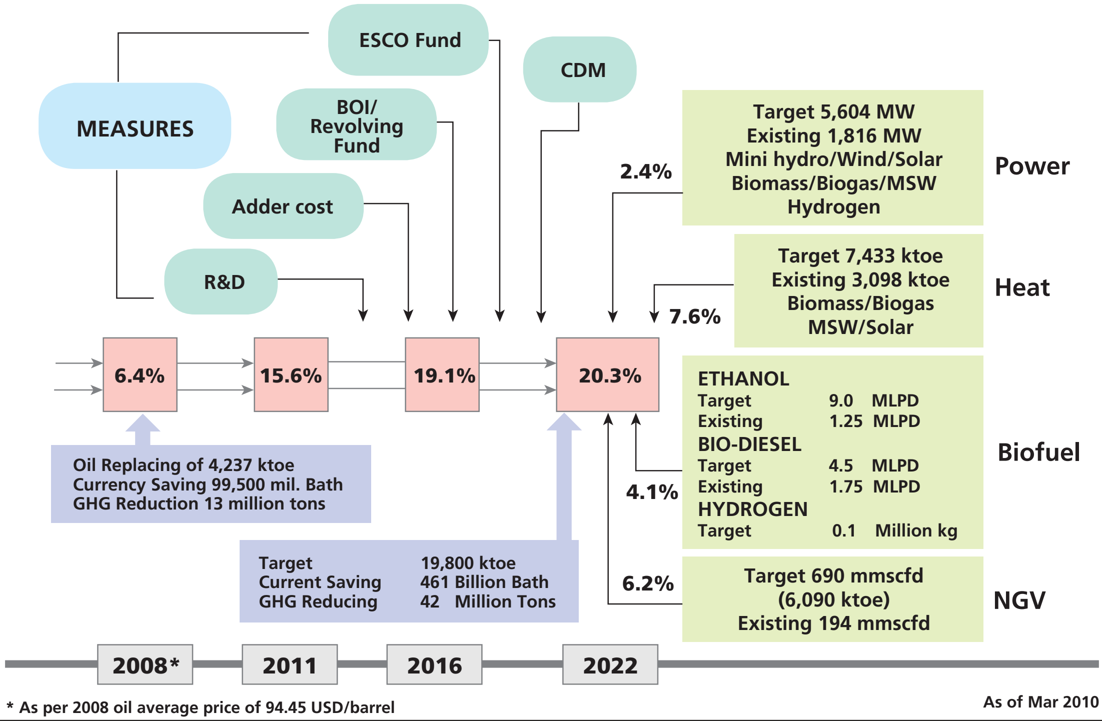
Medium term (2012 –2016). During this phase DEDE will encourage the development a viable alternative energy technology industry with targeted R&D activities in areas such as new technologies for biofuels production and models for development of green cities.

Long term (2017–2022). During this phase focus will shift toward utilizing potential new alternative energy technologies such as hydrogen and bio-hydrogenated diesel (BHD). DEDE will also look for ways to extend green city models throughout Thai communities and to encourage biofuel and alternative energy technology exports in countries in the ASEAN region.

The plan includes volume targets for a wide range of alternative energy sources including electricity and thermal energy from renewable resources and alternative transport fuels including biofuels and natural gas (Figure 2.4).

FIGURE 2.4

Alternative Energy Development Plan

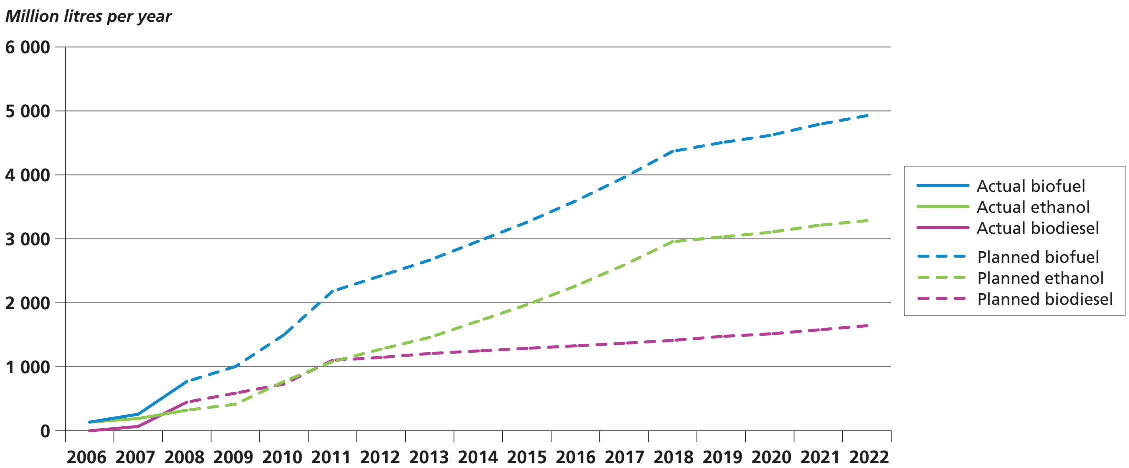


Source: MoE.

In Thailand, the BEFS project focused its analysis on the biofuel sector. The AEDP predicts that Thailand's biofuel output will increase five times by 2022 to almost 5 000 MLPY as illustrated in Figure 2.5. As previously indicated, the biofuel crops envisaged for ethanol production are cassava and sugar cane and oil palm for biodiesel.

FIGURE 2.5

Actual and planned biofuel production under AEDP



Source: MoE.

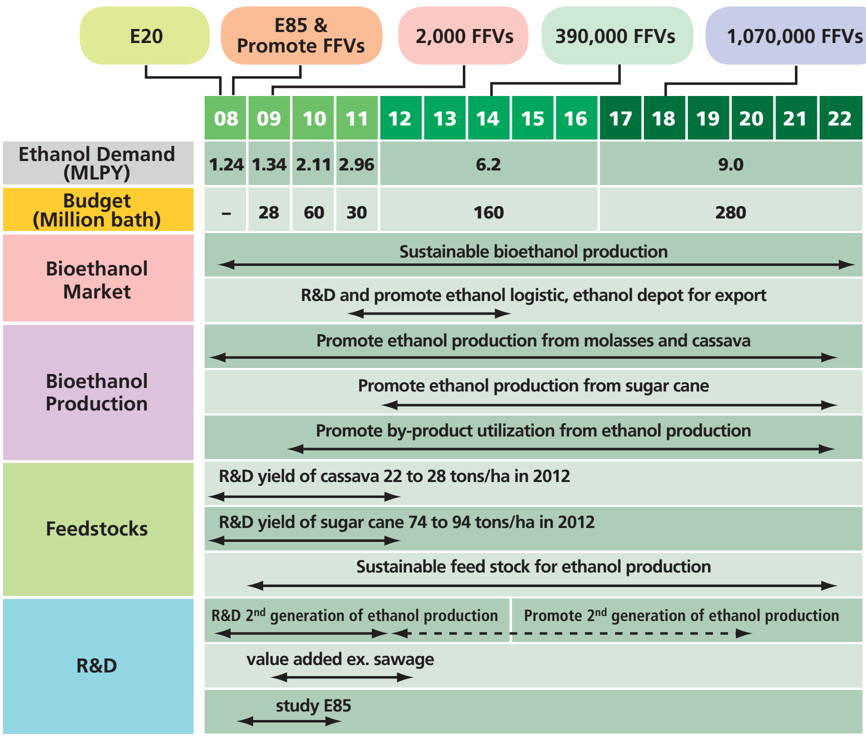
To achieve the anticipated growth in biofuels output the Thai Government has adopted detailed roadmaps for both the ethanol and biodiesel sectors, which are detailed in the next section.

2.1.2 Ethanol sector

Under the roadmap illustrated in Figure 2.6, the increased demand for biofuel crops will be met mainly through increases in yields for both cassava and sugar cane (i.e. molasses). The roadmap also includes provisions for the use of sugar juice harvested from contaminated lands as ethanol feedstock.

FIGURE 2.6

AEDP roadmap for ethanol



Source: MoE.

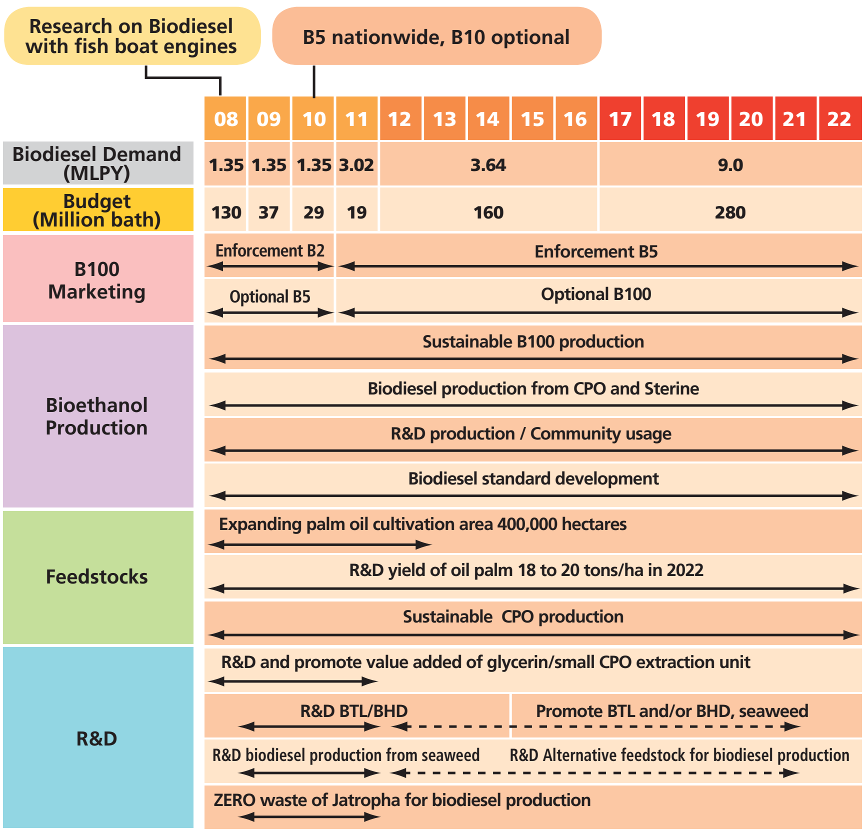
The Thai Government's plan to expand the market for ethanol has encouraged new entrants into the sector with a number of new refineries planned or under construction. However, unlike existing facilities most new production facilities are expected to use cassava as their key feedstock. Once these facilities are complete, production capacity will increase to 3.24 MLPD or 1 180 MLPY.

To facilitate the long-term development of the ethanol sector, the Thai Government plans to support research in areas including investigating ligno-cellulosic ethanol and to promote flexible-fuel vehicles. The gasoline market is small compared to diesel in Thailand, so promoting flexible fuel vehicles will be an important way to expand the domestic market for ethanol in the later years of the AEDP.

2.1.3 Biodiesel sector

A similar roadmap has been developed for the biodiesel sector. A prominent feature of the biodiesel roadmap (Figure 2.7) is the phased introduction of mandatory blending targets – biodiesel blending mandate at 2 percent (B2) in 2008 and at 5 percent (B5) in 2011. To meet the future anticipated demand for biodiesel the roadmap calls for an increase in yield as well as an increase in plantation area for oil palm. The additional land required to meet the target is expected to be as much as 400 000 hectares by 2022, which will double the current harvested area. The Thai Government will conduct research to identify opportunities for algae-based biodiesel, for using jatropha plants as feedstock and for using biomass-to-liquid operations.

FIGURE 2.7
AEDP roadmap for biodiesel



Source: MoE.

Large-scale biodiesel production for blending into fossil diesel began in 2007. In 2008, biodiesel consumption increased to 1.2 MLPD (438 MLPY) and around two MLPD (730 MLPY) in 2009. Refineries planned or under construction will bring the total production capacity to 4.5 MLPD (1 640 MLPY). Large-scale biodiesel refineries are concentrated in the south of Thailand near oil palm plantations and around Bangkok near fossil fuel refineries and fuel distributors. Biodiesel production at small-scale facilities is currently not included in national statistics, but is thought to be minimal.

2.2 THE AGRICULTURE SECTOR

Agriculture has been instrumental in Thailand's economic development and to some degree continues to shape Thai identity, support Thai lifestyles and is strong element of the image the country presents to the world. About one-third of Thailand's total land area of about 51 million hectares is dedicated to agricultural production. Rice is the country's largest crop, but the main cash crops are sugar cane and cassava. There are several annual crops including maize and also perennial crops such as oil palm, rubber, coconut and various fruits.

Expansion of the sector over the past 30 years has been the result of a number of changes both within and outside the sector. The emergence of large-scale food processing, agribusiness and commercial agriculture has had a particularly strong impact on the recent development of the sector and the introduction of new technology and methods has accelerated the production of new crop varieties, use of fertilizer, pesticides and herbicides.

At first, technologies associated with the Green Revolution combining irrigation, fertilizer, high yielding varieties and pest control in a closely managed production environment, were adopted slowly in Thailand. However, by the 1990s, Thailand had become a significant importer of fertilizer and pesticides and developed small local production capacity. Increased use of machinery has also accompanied this transformation in Thailand's agricultural sector.

Although Thai agriculture evolved from wet rice systems, modern irrigation systems were generally imported. Large dam projects were implemented with the aim of increasing rice area and production. Additional dams have become a common policy response to perceived need for additional water resources both in agriculture and hydro-power sectors. In addition, the increased availability of credit for farmers and the creation of the Bank of Agriculture and Agricultural Cooperatives (BAAC) facilitated the types of investment necessary to realize the benefits of technological progress within the sector.

Thailand is now one of the world's leading suppliers of sugar, rice and cassava. Modern mechanization, chemical pesticides and fertilizers in association with large scale irrigation facilities have been crucial in facilitating the regular cycle of agricultural output required to meet the needs of export markets. At present, 77 percent of the value-added in crop agriculture arises from the production of traded goods. Exports of agricultural products amounted to almost 10.5 percent of the total Thai exports in 2004.

Despite expansion of Thai agricultural output over the past three decades, in the last five years the agricultural sector contribution to GDP has declined. However, the sector still continues to be important in terms of employment accounting for approximately 39 percent of the Thailand's labour force (NSO, 2007). The agriculture sector is also an important source of crisis resilience, self-sufficiency and rural social support for poorer rural communities.

Continued development within the sector is necessary to preserve rural livelihoods. The rapid expansion of agriculture was generally made possible by the conversion of forest land to agriculture. Continuation of this practice is no longer practical. As new land for agricultural cropping is now extremely scarce, future increases in production must arise from increases in yield.

However, compared to international standards the average yield per hectare for key crops is at low to medium levels. This has been attributed to a number of factors including:

- physical, chemical and biological deterioration;
- cultivation on steep sloping land without soil conservation practices;
- inappropriate farming systems for increasingly intensive agriculture;
- poorly defined land ownership with associated restrictions of access to fair credit;
- a poorly developed farm credit sector;
- poorly developed agricultural infrastructure;
- irregular rainy seasons.

Government intervention in the sector has been high. The Thai Government is involved in nearly every stage of the agriculture production chain including regulation of agriculture foreign trade, taxation, exchange rates, trade restrictions and the provision of public resources for infrastructure and support of services for agricultural producers. How the Thai Government adapts future policies to address the challenges identified above will have a substantial impact on the future of the sector and its capacity to generate income for future generations of Thai farmers.

2.2.1 Agricultural policy

The development of agricultural policy in Thailand is strongly linked to the Thai Government's national planning process, which began in 1959. From the 1960s through the 2000s the Thai Government has implemented nine five-year National Economic Development Plans each with different implications for the agriculture sector.

Early plans focused on expanding agricultural production to satisfy the demands of the rapidly industrializing economy. A strong focus on industrial development in urban centres led to rural migration. With the arrival of the Green Revolution in the 1970s the national plans looked to rectify long standing issues regarding land title. This was necessary to create the necessary credit in the agriculture sector to encourage the increases in inputs, irrigation and mechanization heralded by the Green Revolution.

By the time of the fourth national plan in 1977 Thai Government policy had started to take greater account social issues arising from issues such as high population growth, low average incomes for farmers, rising unemployment among agricultural workers, low agricultural productivity, low rates of technology adoption by farmers and resistance to new technologies and limited availability of agricultural land. However, due to slow implementation and little progress on these national priorities for the agriculture sector, subsequent plans focused on trying to reverse growing poverty in rural Thailand.

By the commencement of the 1990s agriculture policy became more closely aligned with objectives regarding rural development and exports. At this time particular surplus crops were highlighted for export potential. Subsequent plans aimed to improve the productivity of the agricultural sector while also preserving the environment through the creation of a more sustainable agriculture sector.

With the inception of the Thai biofuels industry in the early 2000s the Thai Government has responded by designing and implementing policies specifically for biofuel crops. Under the 2008 – 2010 action plan for cassava development, the Ministry of Agriculture and Cooperatives (MOAC) adopted a number of measures to improve cassava yields. Also, under the 2008 – 2012 Oil Palm Industrial Development Plan, MOAC is implementing initiatives to encourage expansion of oil palm plantings including low interest loans from BAAC.

In March 2010 a new Memorandum of Understanding was executed between the MoE and MOAC. This is an important measure to ensure that the AEDP is implemented uniformly across all relevant branches of government.

2.3 SOCIAL AND ENVIRONMENTAL ISSUES

2.3.1 Poverty and smallholder farmers

Thailand is a middle-income country that has seen remarkable progress in human development in the last twenty years. The Human Development Index (HDI) for Thailand is 0.783, which ranks the country at 87 out of 182 countries (UNDP, 2009). It will achieve most, if not all, of the global Millennium Development Goals well in advance of 2015. Thailand has reduced the incidence of poverty from 27 percent in 1990 to 11.3 percent in 2004 (UNDP, 2007), and the proportion of underweight children has fallen by nearly half. Most children are in school, and universal primary school enrolment is achievable. Malaria is no longer a problem in most of the country. Annual new HIV infections have been reduced by more than 80 percent since 1991, the peak of the epidemic. Strides are being made toward gender equality.

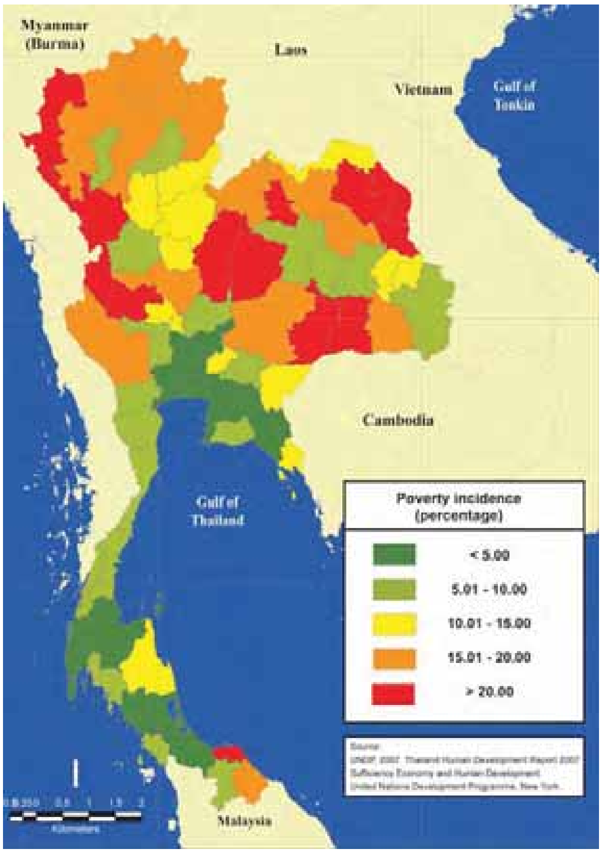
Thailand's success in reducing poverty has been attributed to a mixture of astute policy making, strong democratic governance, an industrious population, public investment in social services, advantageous historic and geopolitical circumstances and, not least, economic growth.

However, despite this success, progress has not benefited everyone equally. Those Thais more closely linked to the international economy have tended to realize the benefits of development much more quickly than others. Meanwhile those Thais who remained in the domestic economy, such as small scale farmers, have generally received fewer benefits, proportionately. As a result, a number of development challenges persist, particularly for certain groups and geographical regions.

Income inequality and lack of social protection and access to services continue to be significant human development concerns. Thailand's cities have grown faster than its countryside. Farmers constitute about 30 percent of the total population of Thailand (i.e. around 20 million) and their numbers are declining by about four percent per year. Their choices and incomes are increasing, but they remain among the poorest part of the population. In fact 87 percent of the poor are farmers and farm workers in rural areas, mainly in the rural northeast, far north and far south of the country (UNDP, 2007) (Figure 2.8).

FIGURE 2.8

Poverty incidence in 2004



Source: UNDP, 2007.

Growing inequality between urban and rural populations will pose threats to future social and political stability in Thailand. Thailand's national development plans have noted that social inequities arising from greater industrialization could be addressed through measures to ensure that greater national wealth benefits the whole populace. However, while Thai agriculture is still dominated by poor smallholder producers, plans to develop the wealth generating capacity of Thai agriculture tend to focus on technological enhancement of commercial agriculture and agribusiness methods. Advanced farm technologies may not necessarily be within practical reach of poor, smallholder farmers.

Despite growing inequality, agriculture in Thailand is both a major source of income through exports and a social welfare system. Smallholders produce the majority of agricultural products including the raw materials utilized by commercial agriculture and agribusiness, while also contributing most of the labour. Labour productivity in agriculture is still low when compared to other sectors. Productivity improvements in the agriculture sector could present the most effective strategy to improve agricultural development that will benefit the poorer rural communities.

Ongoing challenges include higher rates of maternal mortality in the Muslim south, enduring child malnutrition in remote northern hill tribe areas and unsustainable use of natural resources. Additionally, there are warning signs of a resurgence of HIV/AIDS. Women still have fewer career advancement opportunities and display low participation in electoral politics. Domestic violence against women is also a concern among poorer communities. While education reform has been greatly advanced in the last few years, yet gaps remain in terms of quality of education and adaptability to the needs of the economy.

A variety of ongoing and new government policies seek to address these problems. The Cabinet of Thailand's strong endorsement of the UN Millennium Development Goals (MDGs) Report 2004 was a promising step which provided a clear mandate to transform these goals into government policy. This progress will hopefully continue with the integration of additional national development targets outlined in the MDG "Plus" Agenda.

2.3.2 Soil degradation, deforestation and water management

As indicated previously, Thailand's economic growth over the last three decades has been fuelled by rapid industrialization and intensified agricultural production. But this growth, which has relied extensively on the country's abundant and diverse natural resources, has come at a price in terms of land degradation and loss of natural habitats, reduced water quality and increased levels of pollution.

Thai agriculture has significantly changed the natural environment. Departure from traditional farming practices and intensification has degraded soils, while fertilizer and pesticide use have increased without sufficient environmental or health regulatory controls. Fertile, deep, relatively flat, well-drained soils of high natural organic matter have been degraded, and strategies to encourage regeneration are required. Expanding agriculture by opening new lands can now only access marginal and fragile soils, including steep, shallow and skeletal soils, with limited nutrients and moisture.

Water use and availability problems in Thailand may also be underestimated. Open access to irrigation systems has increased strain on some water systems, which could be rectified by appropriate resource pricing schemes. Continued use of chemical herbicides also presents issues in terms of soil and water contamination.

Issues of irreversible changes to the Thai landscape from rice and rubber agriculture, upland deforestation and coastal prawn aquaculture among other activities, changes in water regimes from agriculture and logging, as well as irrigation and uncontrolled groundwater extraction, are now compounded by environmental concerns relating to pollution from agriculture and agribusiness. The long term future of Thailand's natural resources continues to require both the attention of planners and the public.

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CHAPTER 3

AGRICULTURE MARKET PROJECTIONS

As discussed in the previous chapter, Thailand is one of the world's major agricultural producers and is also a food exporting country. For some goods such as cassava, sugar and rice, Thailand is one of the top five exporters globally. This connection to global markets means that many Thai farmers depend on export markets for their livelihood. The share of exports as a proportion of total production is as high as 70 percent. This dependence on export markets implies some risks for Thai farmers; particularly during times of market imbalance. For example, excess supply of agricultural products on global markets put downward pressure on prices, which negatively impacts on the income and livelihoods of Thai farmers. The AEDP and its provisions for development of the biofuel sector provide an option for farmers to stabilize farm incomes in times of high price volatility.

Agricultural markets are continuously reacting to changes in supply and demand. It's essential to understand the likely effects that biofuels might have on commodity markets in order to evaluate the effect of biofuel development in Thailand. Policy needs to be based on detailed assessments of the future supply and demand conditions that might arise in response to biofuel development. Such an assessment will assist policy makers to understand how biofuel demand for feedstocks might affect the commodity market within their country over time and deliver more effective policy responses to benefit Thai farmers.

The objective of this chapter is to present an assessment of how Thailand's agricultural market could possibly be affected by implementation of the AEDP targets for biofuels. Detailed agricultural projections will be developed for each key biofuel feedstock crop as well as other key agricultural crops over a ten year time period. The value of the analysis is not so much the precision of projected values in any one year, but the dynamics of how markets are expected to evolve over the time period assessed.

3.1 COSIMO METHODOLOGY

The agricultural market projections are based on the Commodities Simulation Model (COSIMO) developed by FAO. COSIMO provides projections of production, consumption (i.e. in the form of food, feed, fuel or fibre), imports, exports, stocks and prices. The results can highlight important challenges or opportunities in agricultural markets and provide a picture of how agricultural markets could evolve over time with respect to a set of macroeconomic conditions, trends and current agricultural/biofuel policies.

COSIMO is a partial equilibrium simulation model. The model is determined by elasticities, technical parameters and policy variables. Data inputs for the model come from information provided by national statistics sources and supplemented by external sources such as the United Nations (UN) and World Bank and include:

- Macroeconomic variables, such as population estimates derived from the UN Population Prospects, real GDP, GDP deflator, crude oil price and exchange rates from OECD and World Bank; and
- Agricultural data in terms of quantities produced, consumed and traded from the Trade and Markets Division of FAO.

The model produces a global equilibrium and analyses the effects of international policies on specific country's agricultural markets. All of the major agricultural sectors, including the biofuel sector, are connected and are integrated within the model so that all the main characteristics of the crops and livestock sectors influence the final equilibrium. The extension of the model to include the biofuel sector required technical data that came mainly from country specific information. The technical data were used to generate a world commodity database for ethanol and biodiesel, along with country specific baseline data on different biofuel crops and their processing costs.

In the case of Thailand, the model was used in standalone version, which means that the country information were extrapolated and the projections were generated once country's equilibrium was achieved. This was possible because Thailand is a major supplier of agricultural commodities to the international market and it is assumed that international biofuel policies will have minimal effect on the Thai agricultural market. On the other hand the standalone version allowed the Office Agriculture of Economics (OAE) of the Ministry of Agriculture to revise the basic information with country specific data, without re-balancing the overall global model.

3.1.1 Macro-economic assumptions

The general and country specific assumptions considered in the baseline are as follows:

General assumptions:

- Oil prices are expected to decrease substantially from $97 in 2008 to $62 per barrel in 2009. The oil price then increases with the economic recovery and it is estimated that it fluctuates in the $77-$94 range from 2010-2018. These projections are from the reference scenario reported by the International Energy Agency (IEA, 2009). The projections have the oil price resuming an upward trend and by the end of the period will equal the previous peak in nominal terms. The world oil price will remain well above historical levels. The oil price is an important factor for developments in agricultural markets as it impacts upon energy, transport, fertilizer cost while also setting the basis for the competitiveness of biofuel as an alternative energy source.
- The projections are produced for the period 2009-2018.

Thailand specific assumption:

- Average annual GDP growth is assumed to be 9.3 percent over the whole period, which is consistent with the estimate used by the Thai National Economic and Social Development Board (NESDB);
- The average annual GDP deflator is 4.4 percent (NESDB) and according to the Thai Ministry of Commerce CPI growth is 4.2 percent;
- The domestic currency depreciates in nominal terms against the US dollar at an average rate of -2.4 percent annually. The real exchange rate depreciates by -4.23 percent annually;
- Based on these macro assumptions, real food expenditure, after an initial decrease in 2009 from 2010, increased afterwards. By 2018 the real food expenditure is almost double the 2008 level, and therefore the annual average growth rate is 7.6 percent over the period; and
- Population increases at a 0.52 percent annual rate.

3.1.2 Biofuel assumptions

The purpose of the analysis is to show how Thailand's agricultural market could evolve over time as a result of the implementation of the AEDP biofuel targets. The main assumption is that the AEDP targets, until 2018, will be achieved. Table 3.1 reports the detailed ethanol targets.

TABLE 3.1

Ethanol targets

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Gasoline total consumption	7 811	7 928	8 034	8 154	8 271	8 388	8 503	8 620	8 736	8 853
Anticipated ethanol demand	415	770	1 080	1 278	1 460	1 716	1 971	2 263	2 592	2 957
Potential ethanol mandate (%)	5	10	13	16	18	20	23	26	30	33

Note: the consumption and demand are expressed in million litres per year.
Source: OAE and MoE.

The proportion of the AEDP ethanol targets expected to be produced using either molasses or cassava feedstock are reported in Table 3.2. Whether these proportions can be met depends on the crop production and the existing capacity and configuration of available ethanol production plants. In 2009, there were 17 ethanol plants with total capacity of 2.57 million litres per day. Over half of these facilities are equipped to use only molasses as a feedstock. However, a number of new cassava ethanol facilities are expected to come online in the near future. Based on this assumption cassava production is supposed to increase substantially; mainly through increases in yield. This policy was reflected in the model was reflected by increasing the yield trend coefficient starting from 2010.

In Thailand sugar cane is one of the major cash and export crops the industry is well established. Over the last ten years the average area of harvested sugar cane has remained stable at around one million hectares. The yield in Thailand is generally lower than other major sugar producing countries, especially Brazil and Mauritius, because only a small area of sugar cane is produced on irrigated lands; the rest relies on natural rainfall.

Cassava, like sugar, is another major crop in Thailand with the high potential for export. Fresh cassava roots are either processed directly into cassava starch and then used locally or exported as starch, or the fresh roots are converted into cassava chips and then stored locally and eventually exported as dried chips (called tapioca chips on the international market). The harvested area of cassava has grown slightly by around one million hectares over the last few years, because of increased prices for cassava root. The price increase was mainly attributed to higher world demand for food and fodder.

TABLE 3.2

Share of ethanol targets by feedstock

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Molasses	70%	50%	35%	35%	30%	30%	30%	25%	25%	20%
Cassava	30%	50%	65%	65%	70%	70%	70%	75%	75%	80%

Source: OAE and MoE.

Table 3.3 provides a detailed description of future biodiesel demand anticipated by the AEDP. Palm oil is clearly the feedstock with the most potential to meet future demand for biodiesel in Thailand, accounting for roughly 90 percent of Thailand's crude vegetable oil production.

TABLE 3.3

Biodiesel targets

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Diesel total consumption	15 968	16 284	16 538	16 785	17 028	17 267	17 505	17 745	17 985	18 225
Anticipated biodiesel demand	589	730	1 102	1 146	1 208	1 248	1 288	1 329	1 369	1 413
Potential biodiesel mandate (%)	4	4	7	7	7	7	7	7	8	8

Note: consumption and demand are expressed in million litres.
Source: OAE and MoE.

3.2 THAI AGRICULTURAL MARKET PROJECTIONS

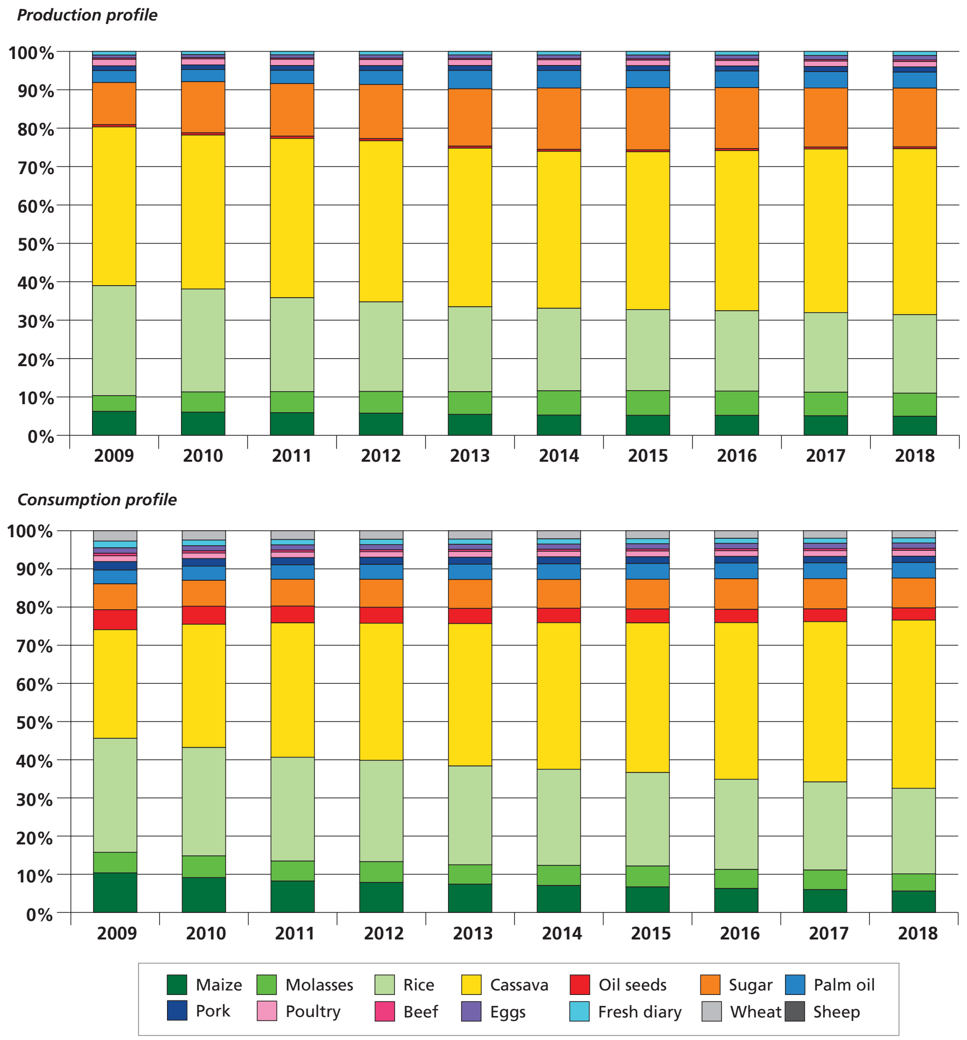
3.2.1 Thailand baseline

Baseline projections on production and consumption trends are presented in Figure 3.1. In presenting the data, coarse grains, roots and tubers and vegetable oil are represented by maize, cassava and palm oil respectively. Sugar cane is presented in terms of molasses and sugar.

The production profile indicates that overall oilseeds will continue to have a small share in the agricultural sector and that wheat is almost zero. Meat, eggs and fresh dairy also account for a small share. On the other hand, rice, roots and tubers and sugar cane will be the most important agricultural crops in terms of production, followed by maize and palm oil.

FIGURE 3.1

Thai projections for production and consumption profile



Source: OAE.

The consumption profile trends indicate that rice and cassava in particular will dominate Thai consumption patterns. Rice remains the largest commodity for food consumption over the period. Cassava increases its share predominantly due to the AEDP and its increased use as a biofuel feedstock. However, it is also anticipated that demand for starch from the sweetener industry will increase. Due to high maize price over the past few years cassava will become an attractive alternative as feed. Throughout the baseline, income growth results in an increased share of food expenditure on meat (i.e. pork and poultry) and vegetable oils, namely palm oil. Maize consumption remains relatively stable and it is mainly due to feed consumption, while wheat consumption increases over the period following growth in GDP.

Table 3.4 shows the production, consumption and net trade projections for the main commodities in the base period (average of the three-year period 2007-2009) and 2018. The full trend of the projections over the ten-year period and the area and yield of the major commodities can be found in Appendix.

Rice

Total consumption is determined only by rice food consumption as a very limited quantity of rice is used as feed, while crushing (milling) rice is not considered in the baseline. Total domestic use is projected to increase on average by 4.5 percent annually following a linear positive trend. Production is expected to decline at the average annual rate of 0.3 percent starting from 2010. This is mainly due to a decrease in the harvested area accompanied by small growth in yields. While the harvested rice area decreases at an annualized rate of almost two percent, yields remain at around 2.3 tons/ha with very small annual growth of around 1.5 percent. Although the country is a net exporter, exports are expected to decline considerably at an average annual rate of 15 percent.

Roots and tubers (cassava)

As discussed above, in Thailand the roots and tubers aggregate category is comprised exclusively of cassava. It is Thailand's second most important crop with an average crop area share of 18 percent. In response to the AEDP, the total area covered by cassava is expected to grow by two percent annually increasing by 350 000 hectares by the end of the period. Yields are expected to grow by two percent annually and reach almost 27 tons/ha by 2018. Consequently production will rise by 15 million tons by 2018. Total consumption is projected to increase more than three-fold over the entire period with a high peak in 2011 when cassava will surpass molasses in the biofuel targets. As noted above, consumption will be driven by increased ethanol production. The country will remain a net exporter of cassava (i.e. chips, pellets and starch) from 2008 to 2018 but the production will be mainly absorbed by greater internal demand. As a result, exports are expected to decline by more than half over the period.

Sugar cane (molasses & sugar)

The harvested area of sugar cane is projected to increase slightly at an average annual rate of around 2.6 percent. Yields are projected to grow from 70 ton/ha in 2009 to almost 80 ton/ha in 2018 resulting in overall growth in national molasses and sugar production. The increase in molasses production will be largely consumed for ethanol production. Sugar production is projected to increase two-fold in-line with GDP growth. Contrary to the situation for cassava, molasses and sugar will continue to be largely exported.

Vegetable oil (palm oil) and oil seeds

As indicated above, vegetable oil in Thailand is mostly comprised of palm oil. Production is expected to double with an average annual growth rate of 8.5 percent throughout the projection period. This increase is due to a projected doubling of oil palm plantations by 2018. The increased consumption is mostly driven by demand for biodiesel. Consumption as food will also increase up to 1.5 million tons by the end of the period largely due to growth in GDP. Thailand remains a net exporter of palm oil but after a positive trend until 2013 it is anticipated that exports of palm oil will decline.

The oil seeds category consists mainly of soybean. Production and consumption are projected to increase over the period. However, consumption will exceed production resulting in increased imports.

Coarse grains (maize)

The maize area is assumed to remain stable over the baseline period and the yield to increase slightly from 3.6 to 4.2 ton/ha by 2018. Better yields explained 80 percent of the projected improvement in production. Maize produced in Thailand is mainly used as feed. Despite a projected increase in production of livestock, maize production is not expected to increase in step due to the substitution of cassava for maize as a principal source of feed. While consumption is expected to exceed supply over the period, little change in Thailand's net trade situation for maize is anticipated in 2018.

Meat

Poultry production is expected to be less than consumption, which is expected to double by 2018. In fact, Thailand's net exports are projected to decrease by 13.2 percent annually. Pork production is expected to meet demand. Thailand is expected to remain a net importer of beef by the end of the outlook period.

TABLE 3.4

Main commodity highlights

	Average 2007-2009	2018	Average annual growth rate [(a)]		Average 2007-2009	2018	Average annual growth rate
Rice				Oil seeds (soybean)			
Production	21 014	19 981	-0.3%	Production	427	484	1.1%
Consumption	11 751	17 931	4.5%	Consumption	2 079	2 549	2.2%
Net trade	8 947	1 728	-14.9%	Net trade	-1 639	-2 068	2.5%
Root and tuber (cassava)				Coarse grain (maize)			
Production	27 387	42 260	4.4%	Production	4 379	4 855	0.9%
Consumption	9 926	35 257	13.0%	Consumption	4 111	4 471	1.1%
Net trade	17 460	7 003	-8.4%	Net trade	267	377	0.1%
Molasses				Poultry			
Production	3 014	5 913	7.0%	Production	1 166	1 374	1.5%
Consumption	2 294	3 626	5.6%	Consumption	615	1 222	8.0%
Net trade	720	2 287	10.0%	Net trade	576	150	-13.2%
Sugar				Pork			
Production	7 884	14 963	6.8%	Production	895	1 336	4.7%
Consumption	2 620	6 267	9.9%	Consumption	879	1 323	4.8%
Net trade	4 586	8 998	11.1%	Net trade	16	13	-3.1%
SugarVegetable oil (palm oil)				Beef			
Production	1 880	4 066	8.5%	Production	241	388	5.8%
Consumption	1 265	3 267	10.0%	Consumption	262	410	5.5%
Net trade	584	782	4.6%	Net trade	-21	-22	0.6%

Note: the values are expresed in thousand tons.
[(a)] The average annual growth rate is calculated by the least square growth rate. It is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period. In the case of negative values it is calculated on absolute values.
Source: OAE.

3.2.2 Low GDP growth rate scenario

The global economic meltdown has impacted Thailand's economy more severely than earlier projected, forcing the World Bank in 2009 to revise its previous annual growth forecast of around two percent to a contraction of 2.7 percent in 2009. In response the World Bank suggested that Thailand accelerate its economic stimulus programs. Based on this information, an alternative scenario was developed incorporating the GDP contraction in 2009 and a revised annual average GDP growth rate of around four percent in the out years as opposed to the NESDB official forecast of 9.3 percent.

The main differences between the baseline and the low GDP growth scenario are as follows:

- area and yield trends of the main commodities are similar to the reference case with high annual GDP growth rate;
- the average annual growth rates of production for each commodity are very similar to the baseline except for pork and beef which were shown to reduce by half;
- consumption is expected to grow at a rate slower than that expected in the baseline. The average annual growth rates of consumption are significantly lower for commodities with high share in food consumption like sugar, rice, palm oil and soybean. In the case of meat the rate of growth in consumption is half that observed in the baseline with production almost matching consumption by 2018;
- for the commodities used as feed, biofuel feedstock or for other industrial uses growth in consumption contracts less than other commodities. The only exception is maize, which is projected to be completely replaced by cassava as a source of feed; and
- Thai economy will tend to reduce exports of rice and cassava considerably less than the baseline over the period; the doubled production of sugar will be absorbed largely by the external market. Overall the international price and demand for Thai commodities will be more favourable compare to the domestic ones.

3.3 CONCLUSIONS

- *Meeting the AEDP biofuel targets will require sizable increases in the production of key biofuel crops: sugar cane, cassava and oil palm*. The agriculture projections indicate that the increase in production will come largely from yield improvements in the case of sugar cane and cassava and expansion of the land area used for oil palm and cassava. The projections seem to indicate that to accommodate the increase in the harvested area of cassava and oil palm, the area of land under rice cultivation may decline by almost two million hectares. The implications of this will be investigated further in the following chapters;
- *To fulfil the targets a reduction in Thailand's exports of rice and cassava are expected*. In the case of rice the decline in exports is the result of the decline in production resulting from reduced harvested area of rice. In the case of cassava the reduction in exports is in response to increases in domestic demand for cassava in the ethanol industry and other domestic uses;
- *Reduction of exports implies that the returns from domestic production of biofuels are assumed to be greater than from exporting the feedstock commodities*. There is a risk that in times of weaker domestic demand and high world prices for biofuel feedstock crops, producers may be tempted to look for opportunities in export markets. The Thai Government will need to ensure that the policy environment for biofuels encourages feedstock producers to supply the biofuel industry;
- *Strong income growth in Thailand translates into increases in food demand and expenditure for sugar, vegetable oil, meat, egg and wheat*. Only in the case of beef and wheat there will be a need to rely on

more imports to meet domestic demand. Although recent economic conditions have put some downward pressure on agricultural commodity prices, they are expected to remain at higher price levels than historic averages. While Thailand's economy remains strong despite the world economic downturn and domestic political instability, it is unlikely that the Thai Government's projections for economic growth will be met. If this is the case, Thailand will tend to export more agricultural produce due to the availability of better prices on international markets. As noted above, whether this will also apply to biofuel feedstock crops depends on the policy environment and incentives provided to producers.

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3.5 APPENDIX

TABLE A3.1

Crop projections

Year	Average 2007-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average annual growth rate(a)
Rice											
Production	21 014	20 811	19 023	18 740	18 729	19 033	19 304	19 554	19 758	19 981	-0.3%
Consumption	11 751	12 836	13 478	14 084	14 673	15 237	15 863	16 435	17 190	17 931	4.5%
Net trade	8 947	5 759	5 328	4 986	4 577	3 608	3 055	2 702	2 199	1 728	-14.9%
Root and tuber (cassava)											
Production	27 387	31 120	32 290	33 705	34 993	36 178	37 565	39 031	40 622	42 260	4.4%
Consumption	9 926	14 618	17 431	19 043	21 163	23 246	25 383	28 532	31 257	35 257	13.0%
Net trade	17 460	16 503	14 859	14 662	13 830	12 932	12 182	10 499	9 365	7 003	-8.4%
Molasses											
Production	3 014	4 073	4 265	4 542	5 016	5 577	5 897	5 937	5 869	5 913	7.0%
Consumption	2 294	2 584	2 595	2 896	2 886	3 200	3 535	3 477	3 820	3 626	5.6%
Net trade	720	1 489	1 669	1 646	2 130	2 377	2 363	2 460	2 049	2 287	10.0%
Sugar											
Production	7 884	10 334	10 652	11 325	12 641	14 135	14 802	14 860	14 685	14 963	6.8%
Consumption	2 620	3 066	3 476	3 875	4 301	4 548	5 043	5 581	5 904	6 267	9.9%
Net trade	4 586	3 981	3 545	4 515	8 121	10 959	7 892	7 011	9 217	8 998	11.1%
Vegetable oil (palm oil)											
Production	1 880	2 480	2 698	2 925	4 065	4 065	4 065	4 065	4 066	4 066	8.5%
Consumption	1 265	1 686	1 875	2 069	2 282	2 476	2 671	2 866	3 067	3 267	10.0%
Net trade	584	772	837	829	1 748	1 575	1 383	1 186	980	782	4.6%
Oil seeds (soybean)											
Production	427	447	455	447	447	453	459	469	477	484	1.1%
Consumption	2 079	2 141	2 178	2 225	2 246	2 301	2 357	2 417	2 481	2 549	2.2%
Net trade	-1 639	-1 710	-1 728	-1 779	-1 796	-1 850	-1 901	-1 952	-2 007	-2 068	2.5%
Coarse grains (maize)											
Production	4 379	4 695	4 609	4 646	4 613	4 679	4 751	4 857	4 847	4 855	0.9%
Consumption	4 111	4 124	4 065	4 150	4 201	4 271	4 325	4 362	4 442	4 471	1.1%
Net trade	267	517	537	492	424	403	422	479	394	377	0.1%

Note: the values are expresed in thousand tons.
(a) The average annual growth rate is calculated by the least square growth rate. It is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period. In the case of negative values it is calculated on absolute values.
Source: OAE.

TABLE A3.2

Livestock projections

Year	Average 2007-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average annual growth rate(a)
Poultry											
Production	1 166	1 225	1 274	1 297	1 320	1 327	1 339	1 338	1 354	1 374	1.5%
Consumption	615	653	713	773	844	898	974	1 042	1 137	1 222	8.0%
Net trade	576	571	561	523	474	428	363	294	214	150	-13.2%
Pork											
Production	895	914	952	1 009	1 060	1 122	1 162	1 221	1 268	1 336	4.7%
Consumption	879	896	935	992	1 043	1 105	1 146	1 206	1 254	1 323	4.8%
Net trade	16	18	17	17	17	17	15	15	13	13	-3.1%
Beef											
Production	241	244	248	257	273	293	317	340	363	388	5.8%
Consumption	262	264	269	278	294	314	338	361	385	410	5.5%
Net trade	-21	-20	-21	-21	-21	-21	-21	-21	-22	-22	0.6%

Note: the values are expresed in thousand tons.
(a) The average annual growth rate is calculated by the least square growth rate. It is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period. In the case of negative values it is calculated on absolute values.
Source: OAE.

TABLE A3.3

Area and yield projections for the major commodities

Year	Average 2007-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average annual growth rate[(a)]
Rice											
Area	10 629	10 192	9 272	9 023	8 897	8 906	8 908	8 902	8 877	8 857	-1.7%
Yield	1.98	2.04	2.05	2.08	2.11	2.14	2.17	2.20	2.23	2.26	1.4%
Root and tuber (cassava)											
Area	1 228	1 347	1 371	1 404	1 431	1 451	1 478	1 507	1 539	1 571	2.3%
Yield	22.29	23.10	23.55	24.00	24.46	24.93	25.41	25.90	26.40	26.90	2.0%
Sugar cane											
Area	962	941	964	1 006	1 094	1 186	1 210	1 188	1 140	1 117	2.7%
Yield	69.44	73.41	73.52	74.03	74.73	75.52	76.74	77.50	78.30	79.58	1.3%
Vegetable oil (palm oil)											
Area	506	675	730	786	1 107	1 090	1 074	1 058	1 042	1 027	7.7%
Yield	3.00	3.09	3.14	3.19	3.23	3.28	3.33	3.38	3.43	3.49	1.6%
Oil seeds (soybean)											
Area	300	303	305	296	292	291	291	293	295	295	-0.4%
Yield	1.42	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.62	1.64	1.5%
Coarse grains (maize)											
Area	1 201	1 238	1 204	1 196	1 171	1 171	1 172	1 182	1 165	1 152	-0.6%
Yield	3.65	3.79	3.83	3.89	3.94	4.00	4.05	4.11	4.16	4.21	1.5%

Note: the area refers to harvested area and is expresed in hectares; the yield is expressed in tons/ha.
[(a)] The average annual growth rate is calculated by the least square growth rate. It is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period. In the case of negative values it is calculated on absolute values.
Source: OAE.

CHAPTER 4

NATURAL RESOURCE ANALYSIS: LAND

It isn't completely clear how bioenergy crops affect food production and consequently food security. In order to monitor any changes, it is important to have a clear picture of Thailand's staple food crops and their primary growing regions. Any plan for bioenergy production must be managed carefully to ensure that it does not have a negative effect on food production. Thailand currently produces an adequate amount of its main bioenergy crops – oil palm for biodiesel and sugar cane and cassava for ethanol – for its domestic use and for export. But, demands for both food and energy are increasing. Thailand must increase considerably its productivity and expand its cultivation of land for bioenergy crops if it is to meet the AEDP targets, but not at the expense of staple food crops or of forests and other environmentally vulnerable areas. It is essential to conduct scientifically sound assessments of the natural resources – in particular assessments of land and water – that are necessary for such an ambitious plan.

As previously discussed, agriculture is a key sector of Thailand's economy. Greater recognition of the importance of agriculture and improved planning are essential to continued economic growth and continued poverty reduction. It is possible to increase the agricultural production in order to accommodate the bioenergy and the food market but it should be managed sustainably while respecting protected areas and biodiversity.

The main objective of this chapter is to assess the potential of biofuel crop production to fulfil the AEDP from a land perspective. Land is one of the natural resources that should be considered carefully in order to evaluate which areas are better suited to which crops and which ones are available for bioenergy crops, taking environmental and food security issues into account.

There are three main crops indicated in the AEDP: sugar cane, cassava and palm oil. An analysis of these three main crops follows the brief description of the methodology.

4.1 THE METHODOLOGY OF LAND ASSESSMENT

The methodological framework of the land assessment is composed of two main elements: the land suitability assessment and the availability of suitable land. The land suitability assessment (LSA) is based on a zoning approach developed and used by FAO since 1978. LSA considers a range of climatic (i.e. temperature and rainfall) and soil related geo-referenced (i.e. pH, nutrients, slope) elements to identify the most suitable areas for growing the key biofuel crops and to understand how much of each crop can be produced given specific agricultural practices and levels of inputs. The suitability of a given portion of land is expressed as a percentage of the maximum attainable yield for each crop.

Once the suitable land is identified, an analysis of the availability of such land helps to draw a more realistic picture of the potential land area and biofuel crop production; and, it makes clearer the trade-offs among bioenergy development, food production and environmental protection.

In Thailand the Land Development Department (LDD) of the Ministry of Agriculture is responsible for the land assessment. It is also responsible for training farmers to improve the use of soil resources, promoting better agricultural management in terms of water and soil conservation, and for supporting and expanding the use of organic fertilizers. The main objective is to accelerate agricultural development and to increase productivity in terms of both quality and quantity while also reducing production costs especially in poor areas. With this in mind, LDD developed a tool to support farmers called Thai Soil Management Simulation Farming (TSM_SIMFARM).

4.1.1 Land Suitability Assessment

The LSA is used to evaluate the suitability of a specific location for producing a particular crop under a well-defined agricultural management system based on the agro climatic, soil and landform conditions. The LSA then evaluates the potential production and return for such areas. There are three steps to this analysis:

- define the Land Utilization Type (LUT), which is a combination of crop, production system and level of inputs;
- create the land resource inventory, which is geo-referenced information on climate, soil and landform; and
- formulate the climatic and soil-related suitability assessment criteria.

The criteria are formulated by interpreting climate and soil related information as limiting factors to achieve the maximum attainable yield for a specific LUT.

A detailed flowchart of the LSA methodology (Figure A4.1) and the specific suitability assessment criteria (Tables A4.1-2-3) used for defining the suitability of palm oil, sugar cane and cassava in Thailand can be found in Appendix.

To define the maximum attainable yield, LDD has collected yield information through field visits and interviews with farmers, who were selected through a multi-stage, stratified, random sampling technique. Figure 4.1 shows the locations of 380 farmers working on sugar cane, 281 on cassava and 211 on oil palm.

The suitability index is defined as the potential of a specific location to achieve a certain percentage of the maximum attainable yield for a specific crop because of its agro-climatic and soil conditions. In Thailand the suitability index has four classes that are defined slightly differently from the ones identified in the FAO methodology, but are still comparable. Table 4.1 describes the suitability classes and the corresponding achievable yields for the biofuel crops analyzed in the Thai context. It could be worst to clarify that the information on yield and area by crop reported in this chapter is referred to planted area as the objective of this study is the land assessment. Conversely the information provided by OAE and in the AEDP refers to harvested area.

TABLE 4.1

Attainable yield by suitability class for the key biofuel crops

Suitability Class	Achievable yield* (%)	Sugar cane (ton/ha)	Cassava (ton/ha)	Oil palm (ton/ha)
Very suitable	95 – 100	69.6 – 73.3	27.6 – 29.0	26.6 – 28.0
Suitable	60 – 95	44.0 – 69.6	17.4 – 27.6	16.8 – 26.6
Moderately suitable	40 – 60	29.3 – 44.0	11.6 – 17.4	11.2 – 16.8
Marginally suitable	0 – 40	< 29.3	< 11.6	< 11.2

* Of the maximum attainable yield.
Source: LDD.

LDD also collects much more information at the farmer level. Based on a Logistic Regression Analysis (LRA), this information is used to calibrate and adapt the LSA results to the reality on the ground.

FIGURE 4.1

Sampling points for sugar cane, cassava and oil palm

Source: LDD.

4.1.2 Availability of suitable land

The suitability assessment considers all the land as potential area for expanding each crop. However, not all the land is available for agricultural expansion and bioenergy development for various reasons. The availability of suitable land is closely related to political needs and priorities. Areas designated for other use, such as urban areas, or areas assigned by law to commercial activities, such as forestry concessions, cannot be considered even if their suitability is very high. Areas with environmental concerns or areas already under agricultural food production should be analyzed carefully.

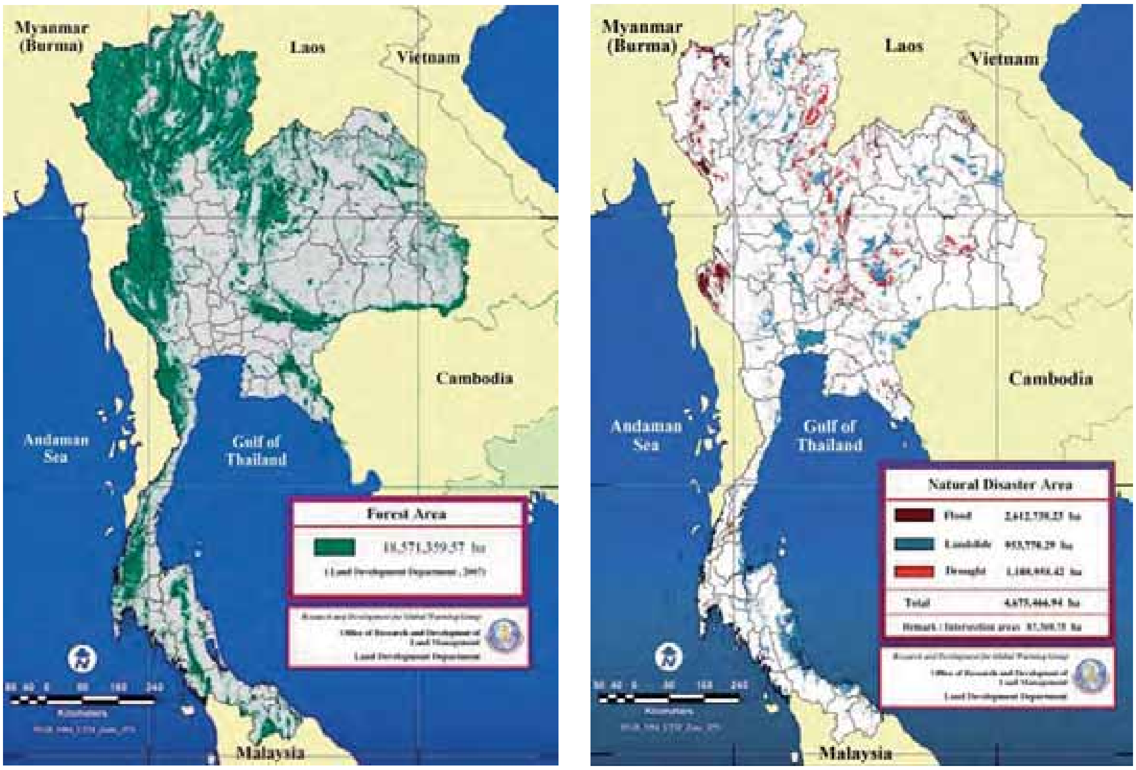
Over the last 20 years, deforestation has become a serious concern in Thailand. Designating particular areas as forest reserves has not protected these lands from agricultural expansion. Forest land, national parks, conservation area, wildlife and sanctuaries account for about 36 percent of the total land area, equivalent to more than 18 million hectares. Such areas have been subtracted from the potential area suitable for bioenergy crop production in order to ensure that bioenergy crops do not encroach upon protected lands.

Thailand is affected periodically by natural disasters such as floods, landslides and droughts that, in turn, affect the country's agricultural production. Floods affect about 9.2 percent of arable land, landslides about 3.4 percent and drought about 3.9 percent.

Areas prone to natural disasters are also subtracted from suitable land because of the high risk of losing crops. Almost five million hectares of land are affected by natural disasters and this represents nine percent of the total land area. Figure 4.2 shows where forest and natural disasters occur.

FIGURE 4.2

Forests and natural disaster area



Source: LDD.

4.1.3 A tool to support farmers

Increasing the use of fertilizer has played a major role in increasing the supply of food to a continually growing world population. Similarly, higher demand for specific crops, as is occurring with biofuel crops, could lead farmers to follow the same path. However, focusing attention on the most important nutrients, such as nitrogen, has in some cases led to nutrient imbalances, to excessive applications of nitrogen, to inefficient use of nitrogen fertilizer causing large environment damage such as lower air and water quality, decreased biodiversity and human health concerns. Better management of all essential nutrients in conventional production systems is required if a more sustainable agriculture that maintains the necessary increases in crop production while minimizing waste, economic loss and environmental impacts is to be developed. More extensive production systems such as conservation agriculture and organic farming may prove to be sustainable. Increasingly, land managers will need to conform to good agricultural practices to achieve production targets and to conform to environmental targets as well. Soil information has become a necessary part of any decision involving a specific site.

TSM_SIMFARM, LDD's computer-based decision support tool, determines the best-bet fertilizer strategies for a range of target yields for a specific crop, given soil nutrient supplying capacity, potential yields and nutrient recovery rates. Based on detailed site-specific information, this tool can provide quick and cost effective answers for the crop under investigation to such questions as:

- how much fertilizer should be applied;
- which is the best composition of chemical and organic fertilizer;
- how much can the inputs' cost be reduced based on appropriate application of the inputs; and
- how much to irrigate, calculating the minimum amount of water available to an individual farm.

With this tool, the LDD supports farmers with clear information to increase their yields for each specific crop and, as a consequence, helps them to improve the suitability of the land. TSM_SIMFARM also helps them to reduce their production costs, which increases their returns.

LDD provides a cost-benefit analysis to help farmers identify which crop could provide the highest return, and whether or not to consider a potential crop change (Table A4.4 in Appendix). However, the behaviour of Thai farmer's is dictated by the market. They seek higher returns and therefore change crops according to commodity prices. This is the main reason for increased supplies and lower prices for some commodities.

4.2 RESULTS

In order to meet AEDP targets, the productivity of existing lands under cultivation must be improved and eventually biofuel crops must expand cultivation to new areas. The following looks at the three main bioefuel crops in detail.

The suitability classification of existing lands under cultivation is applied based on the yield information collected in the field. The suitability assessment as described in Section 4.1.1 is carried out on total land.

4.2.1 Sugar cane

The actual area that is currently used to produce sugar cane is only a little more than 1.6 million hectares. More than 90 percent of sugar cane in Thailand is cultivated under rainfed conditions. The maximum potential yield is around 70–75 tons/ha. Currently, 45 percent of sugar cane plantation is being grown with yields of less than 29 tons/ha classifying the land as marginally suitable land. The next biggest area of sugar cane cultivation is classified suitable land since higher yields are achievable (Table 4.2).

TABLE 4.2

Area under sugar cane cultivation by suitability class

Suitability Class	Irrigated ha & %	Rainfed ha & %	Total ha & %
Very suitable	8 885 8.9	96 894 6.4	105 779 6.5
Suitable	60 264 60.7	519 407 34.4	579 671 36.0
Moderately suitable	4 623 4.7	209 106 13.8	213 729 13.3
Marginally suitable	25 458 25.7	687 333 45.5	712 791 44.2
Total	99 230 6.2	1 512 740 93.8	1 611 970

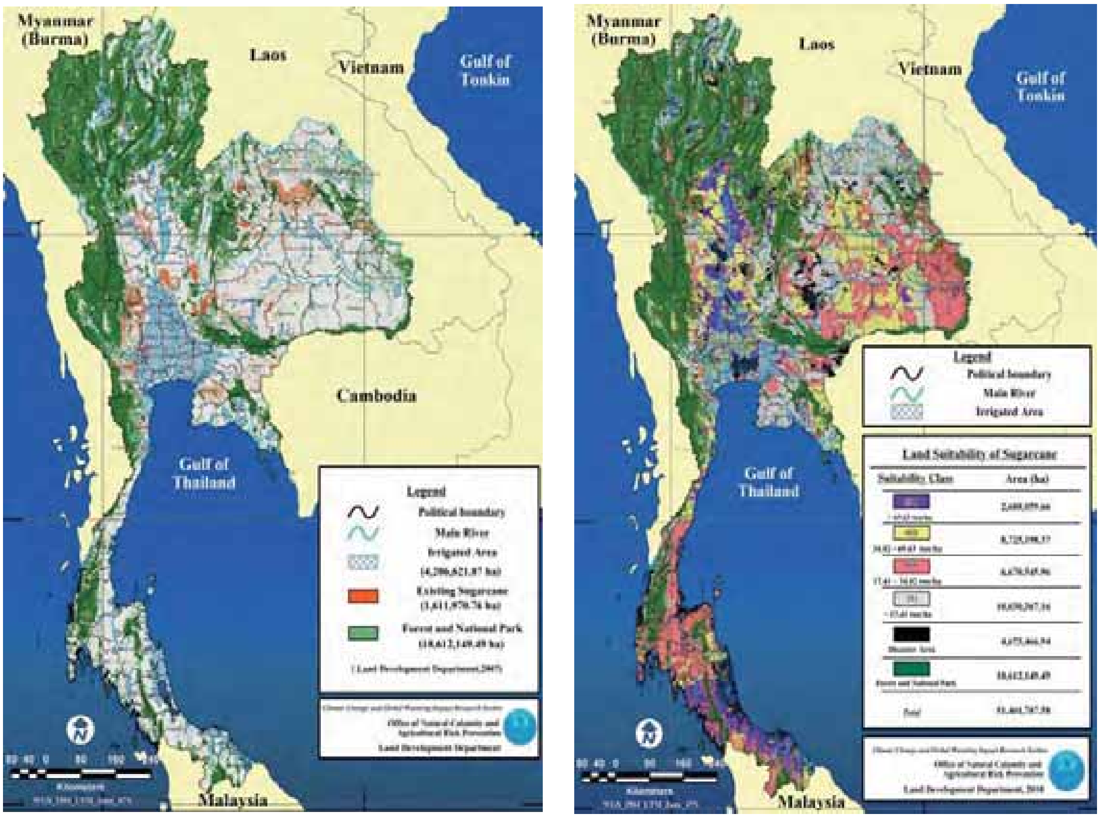
Source: LDD.

Better agricultural management, such as appropriate use of fertilizers or best combination of chemical and organic fertilizer based on the soil profile and efficient use of irrigation, could improve the suitability of these areas. In particular, it could help to raise the suitability of the largest area up to moderately suitable with an increase of the yields up to 44 tons/ha. Furthermore, TSM_SIMFARM provides farmers with a cost analysis of the improvements so they can evaluate potential costs or benefits connected to upgrading.

The suitability assessment shows almost 2.7 million hectares of very suitable land and 8.7 million hectares of suitable land available for sugar cane cultivation in Thailand (excluding forests, protected areas and areas prone to natural disasters). The very suitable areas are concentrated mainly in the central provinces and also in Phatthalung and Songkhlain in the south. Suitable areas are located around the central provinces and in the north-eastern region. Figure 4.3 shows the location of the actual area under sugar cane production and the potential land by suitability class. In particular, the area in purple corresponds to very suitable land and the suitable land is indicated in yellow.

FIGURE 4.3

Actual versus potential area for sugar cane by suitability class



Source: LDD.

The suitable land identified as available after having excluded areas for environmental reasons could be already partly under agricultural production. In terms of crop promotion, the suitable land could be used for other crops, mainly cash crops with higher values and returns for farmers. Table 4.3 shows that the area where sugar cane could achieve the maximum yield (very suitable) is already almost 70 percent under rice and rubber production, and another ten percent of the land cannot be used because it consists of urban area and water bodies.

TABLE 4.3

Actual use of available suitable land for sugar cane

	Irrigated					Rainfed				
	ha					ha				
	1	2	3			1	2	3		
Very suitable	Rice	Urban	Rubber	...	Sugar cane (4)	Rice	Rubber	Water body	...	Sugar cane (5)
	473 685	87 416	66 767		8 885	738 421	587 792	139 955	...	96 894
Suitable	Rice	Urban	Sugar cane	...	...	Rice	Maize	Sugar cane	...	...
	881 184	178 148	60 264	...	...	3 301 311	597 465	519 407	...	...
Moderately suitable	Rice	Maize	Urban	...	Sugar cane (8)	Rice	Rubber	Oil palm	...	Sugar cane (8)
	182 929	38 886	37 738	...	4 623	2 353 699	1 301 923	410 965	...	209 106
Marginally suitable	Rice	Urban	Cassava	...	Sugar cane (6)	Rice	Cassava	Maize	...	Sugar cane (4)
	498 507	134 884	79 531	...	25 45	3 520 417	731 486	709 978	...	687 333
	Total sugar cane plantation				99 230	Total sugar cane plantation				1 512 740

Source: LDD.

Fifty-five percent of the suitable land is already under rice and maize production, and another four percent cannot be used. Considering the area already under sugar cane production described above, the very suitable and suitable land available for expanding sugar cane is respectively around 300 000 hectares where the maximum yields could be achieved and two million hectares where sugar cane yields could reach 40 to 70 tons/ha.

The potential land expansion and resulting crop changes will be feasible for farmers only from the perspective of the cost/benefit analysis. Based on the information in Table A4.4 in Appendix, farmers could look at the costs and benefits of a portfolio of crops to evaluate the most appealing situation.

4.2.2 Cassava

About 1.6 million hectares of land is currently being used for cassava. Cassava production is currently produced under rainfed conditions. Fifty-five percent of the area under cassava cultivation is classified marginally suitable due to yields below 12 tons/ha. Most of the remaining area is moderately suitable with yields between 12 and 17 tons/ha, which is about half of the yields in very suitable land (Table 4.4).

Cassava is usually considered to be a low-value crop with minimal returns for farmers, which contributes to its current low yield. Yields can be increased with the use of improved varieties, pest and disease control and with better practices such as appropriate use of nutrients to restore soil nutrients and fertility. But, such practices require investments. An increased demand and higher prices for cassava might provide enough incentive to encourage farmers to adopt some of these better practices. This should help to improve the cassava suitability in particular of the largest area actually classified as marginally suitable due to the low yields.

TABLE 4.4

Area under cassava cultivation by suitability class

Suitability Class	Irrigated	Rainfed	Total
	ha & %	ha & %	ha & %
Very suitable	2 822 16.0	151 003 9.3	153 825 9.4
Suitable	2 052 11.7	162 518 10.1	164 570 10.1
Moderately suitable	8 767 49.8	413 527 25.6	422 294 25.8
Marginally suitable	3 954 22.5	889 120 55.0	893 074 54.7
Total	17 595 1.1	1 616 168 98.9	1 633 763

Source: LDD.

Based on the suitability assessment such land is classified as moderately suitable and the improvements described above could lead to increase the yield on average of five tons/ha. Similar upgrading toward the suitable class it is feasible for the moderately suitable land.

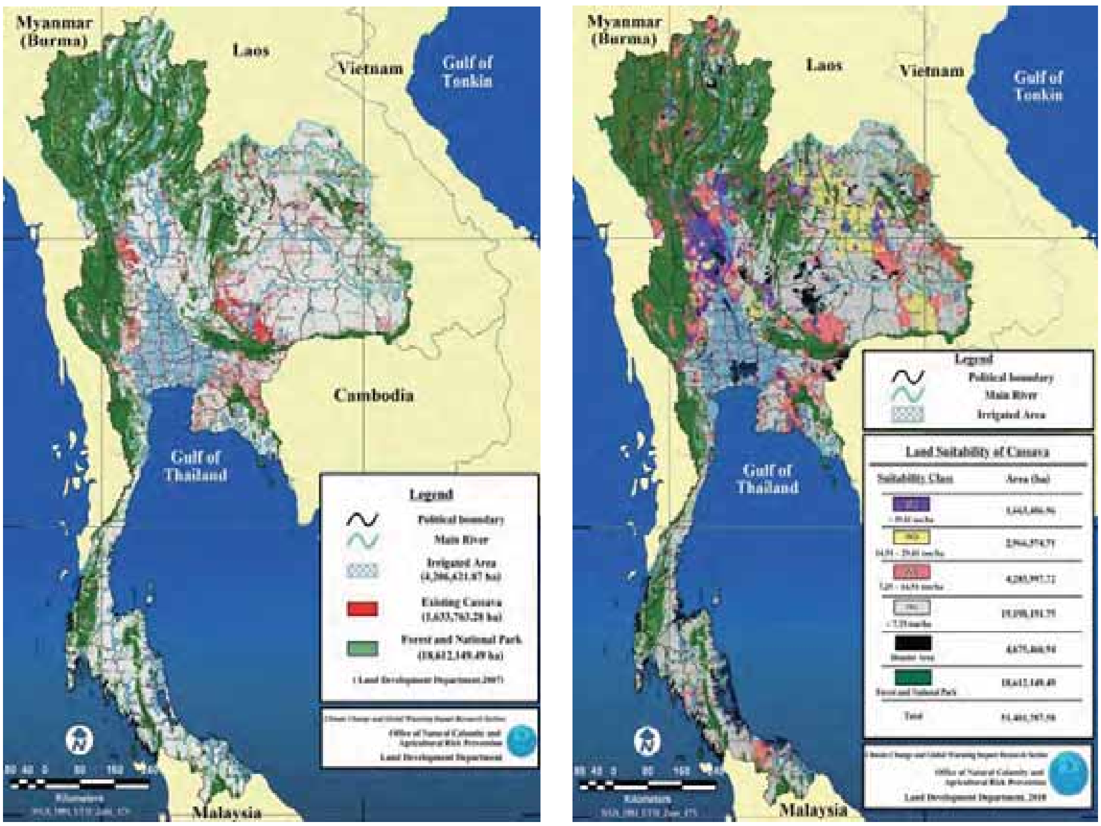
The AEDP expects a large increase in the demand for cassava bioethanol to meet its targets. The increased demand is expected to be met by increasing the average yield of cassava from 23 to 28 tons/ha. It does not expect land cultivation for cassava to expand.

The suitability assessment indicates that such an increase in yields is feasible, but it will not be possible to maintain the existing export markets and meet the additional demand from the cassava ethanol industry. Raising the productivity, and consequently the suitability, of existing cassava crop land will require considerable effort to be achieved in short term.

Crop expansion could be another way to increase production if yields are not sufficiently high. The actual production is largely located in the north-east in Nakhon Ratchasima province, in the centre in Kampaeng Phet and in the east in Chachoengsao. The suitability assessment shows 1.6 million hectares of very suitable land and 2.9 million hectares of suitable land for cultivating cassava after having excluded the environmental areas. The most suitable areas are mostly located in the central and north-eastern regions as shown in Figure 4.4.

FIGURE 4.4

Actual versus potential area for cassava by suitability class



Source: LDD.

Looking at the most suitable land after having excluded environmentally sensitive areas and at the actual land use (Table 4.5), ten percent of this land is already under cassava production and 65 percent is under other agricultural production. Mainly the area is under rice and sugar cane cultivation leaving 400 000 hectares available for expanding cassava without affecting other crops. The suitable land for cassava is mainly cultivated with rice, sugar cane and mixed crops. The potential area for expansion is around 900 000 hectares.

TABLE 4.5

Actual use of available suitable land for cassava

	Irrigated					Rainfed				
	ha					ha				
	1	2	3			1	2	3		
Very suitable	Rice	Sugar cane	Urban	...	Cassava (6)	Rice	Sugar cane	Cassava	...	...
	128 692	15 324	9 800	...	2 822	747 363	184 697	151 003	...	...
Suitable	Rice	Urban	Mixed crops	...	Cassava (13)	Rice	Mixed crops	Sugar cane	...	Cassava (5)
	112 133	25 272	14 154	...	2 052	1 253 858	241 689	213 063	...	162 518
Moderately	Rice	Rubber	Urban	...	Cassava (7)	Rice	Cassava	Maize	...	...
suitable	195 636	45 037	34 634	...	8 767	1 753 914	413 527	332 282	...	...
Marginally	Rice	Urban	Mixed orchard	...	Cassava (45)	Rice	Rubber	Maize	...	Cassava (5)
suitable	1 599 543	350 435	157 900	...	3 954	6 105 233	413 527	332 282	...	889 120
	Total cassava plantation				17 595	Total cassava plantation				1 616 168

Source: LDD.

As already discussed cassava delivers minimal returns for farmers. Promotion for expansion, improvement and crop change will require a great deal of effort, mainly to assure the highest and competitive returns. Particular attention should be paid to the possibility of a crop change that could have a negative effect on GHG balance as described more in-depth in Chapter 7.

4.2.3 Oil palm

Oil palm is being cultivated on nearly 630 000 hectares of land, largely in the south and classified as suitable and moderately suitable area (Table 4.6). Suitable land can produce yields as high as 28 tons/ha, but the maximum yield for moderately suitable land is only about half that amount.

Oil palm yields have been shown to increase through better management practices and by limiting chemical fertilizers in favour of organic methods and products, which also reduces production costs. Such practices can also raise the suitability of the land that is already being cultivated.

TABLE 4.6

Current area under oil palm cultivation by suitability class

Suitability Class	Irrigated	Rainfed	Total
	ha & %	ha & %	ha & %
Very suitable	16	889	905
	0.1	0.1	0.2
Suitable	10 203	318 586	328 789
	32.0	53.5	52.4
Moderately suitable	21 038	275 585	296 623
	66.0	46.3	47.3
Marginally suitable	622	282	904
	1.9	0.1	0.1
Total	31 879	595 342	627 221
	5.1	94.9	

Source: LDD.

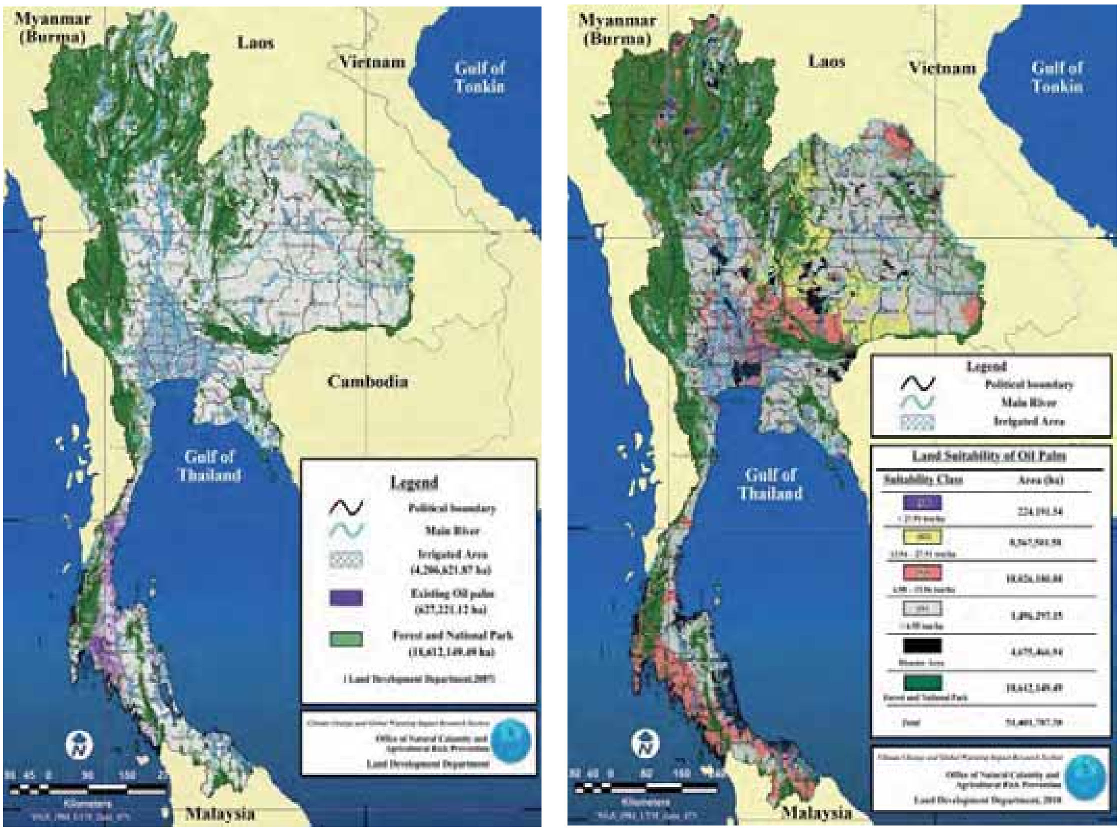
The AEDP predicts that oil palm plantations could increase by as much as 400 000 hectares in an effort to meet Thailand's biodiesel targets. Based on the assessment, there are an additional 200 000 hectares of very suitable land in the south and about 8 million hectares of land considered suitable for oil palm production mainly located in the north-east, as shown in Figure 4.5.

In terms of competition with other crop production, oil palm production is very suitable in the south in areas largely already under rice and rubber production. There is very limited opportunity for expansion in the rubber area because of its high returns. More than half of the suitable land is already in use with again rice and rubber plus maize leaving available around three million hectares, mainly located in the north-eastern region (Table 4.7 and Figure 4.5).

Oil palm could produce better returns for farmers in these areas than some of the key crops currently under cultivation such as rice and maize. Expanding oil palm production into the north-east could provide improved financial returns for farmers in the region and have a positive effect on rural development.

FIGURE 4.5

Actual versus potential area for oil palm by suitability class



Source: LDD.

TABLE 4.7

Actual use of available suitable land for oil palm

	Irrigated					Rainfed				
	ha					ha				
	1	2	3			1	2	3		
Very suitable	Rubber	Rice	Mixed orchard	...	Oil palm (13)	Rice	Water body	Rubber	...	Oil palm (25)
	6 040	5 582	1 324	...	16	128 035	54 381	40 629	...	889
Suitable	Rice	Urban	Rubber	...	Oil palm (16)	Rice	Rubber	Maize	...	Oil palm (6)
	372 190	105 283	98 438	...	10 203	2 051 504	1 362 343	606 734	...	318 586
Moderately suitable	Rice	Urban	Rubber	...	Oil palm (13)	Rice	Rubber	Cassava	...	Oil palm (12)
	990 765	169 508	100 392	...	21 038	6 639 615	1 564 312	1 051 262	...	275 585
Marginally suitable	Rice	Urban	Sugar cane	...	Oil palm (46)	Rice	Cassava	Maize	...	Oil palm (78)
	667 934	142 157	39 203	...	622	1 093 567	362 603	240 016	...	282
	Total oil palm plantation				31 879	Total oil palm plantation				595 342

Source: LDD.

4.3 CONCLUSIONS

- *The required expansion of biofuel crop production is feasible but should be carefully planned to avoid deforestation, biodiversity loss, expansion into areas affected by natural disasters and excessive harmful crop changes*. In the short-term, the targets envisaged by the AEDP are achievable, but, as noted below, will require strong improvement in yields. As discussed in Chapter 3, over the long-term, achievement of the AEDP targets will require an expansion of the land area allocated to biofuel crops. If not managed correctly, such an expansion could result in a number of negative environmental externalities such as increased GHG emissions and loss of biodiversity and soil organic matter. Issues associated with GHG emissions from potential land use and crop changes arising from the expansion of biofuel feedstock crop production are examined in more detail in Chapter 7.
- *Potential yield improvements of the key biofuel crops are feasible through more efficient and sustainable agriculture management*. Sustainable agricultural management techniques such as conservation agriculture, organic farming methods and careful use of organic rather than chemical fertilizers could help the farmers to achieve yield improvements while also respecting the environment and providing higher returns through reduced costs for equipment, labour and fuel. a As noted in Chapter 2, the declining productivity of agricultural land is a growing problem for Thai farmers. Sustainable agriculture practices will help to improve the long-term productivity of the land resulting in more stable yields and reduced the soil erosion. Sustainable agricultural practices are also more likely to reduce GHG emissions from farming as discussed in Chapter 7 and enhance the resilience of the natural resource base required for agricultural production. To realize yield improvements and take advantage of more sustainable agricultural practices the provision of assistance in terms of agricultural extension services is necessary. Thailand is producing its agricultural products under rainfed condition, except for rice. Irrigation could be another way to improve yields. Potentials and implications of the use of water resource are described in detail in Chapter 5.
- *Technical support and extension services for farmers will be required to increase biofuel crop production and fulfill the short-term targets of the AEDP*. Farmers require technical support and up-to-date information to optimize yield and returns. A wealth of agronomic information is available from the Thai Government that will be essential to encourage the yield improvements necessary to meet the AEDP biofuel targets. Action is required to bridge the gap between farmers, farmer's organizations and government to improve the delivery of agricultural extension services and relevant information regarding land productivity, yield

and price. The role of farmers' organizations in facilitating the transfer of agricultural technology and techniques between farmers and the Thai Government will need to be strengthened.

- *Monitoring of the AEDP targets over the long-term is required to prevent the risk of any harmful land and/or crop use changes*. The AEDP targets must be monitored over the long-term to ensure that efforts to raise agricultural production and productivity to meet the targets do not cause environmental harm or threaten food security. While policy certainty will be crucial in overcoming a number of the challenges inherent in the AEDP, the Thai Government must retain the ability and capacity to regularly assess progress toward the targets and re-evaluate policy in the face of changing circumstances.

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4.5 APPENDIX

FIGURE A4.1

Land Suitability Assessment flowchart

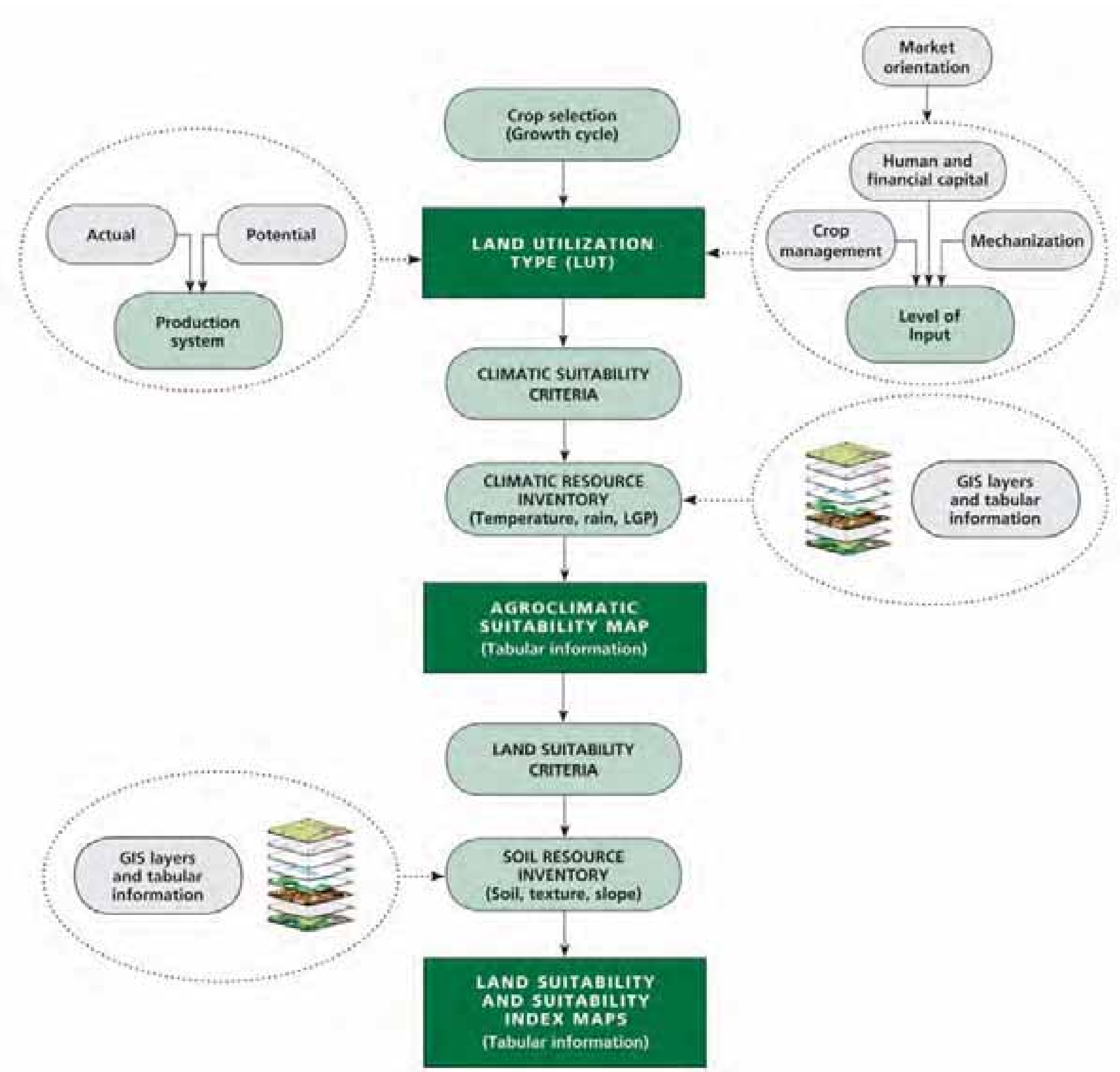


TABLE A4.1

Suitability Assessment Criteria for sugar cane

Factors			Suitability Assessment Criteria			
Attribute	Diagnostic	Unit	Very Suitable	Suitable	Moderately Suitable	Marginally Suitable
	Temperature	°C	>24	< 24	–	–
Moisture	Rainfall	Mm	1200 – 2500	2500 - 3000 900 - 1200	3000 - 4000 –	> 4000 < 900
Oxygen	Soil drainage	Class	5, 6	3, 4	2	1
Nutrient availability	Nutrient status P K Organic matter	Class ppm Ppm %	VH, H > 25 > 60 > 2.5	M, L 6 – 25 30 – 60 1 – 2.5	– 0 – 6 0 – 30 0 – 1	– – – –
Nutrient retention	C.E.C. subsoil B.S. subsoil	meq/100g %	> 15 > 35	5 – 15 < 35	< 5 –	– –
Rooting condition	Soil and Water depth Root penetration	Cm Class	> 100 1, 2	50 – 100 3	25 – 50 4	< 25 –
Salt excess	EC. of saturation	dS./m	< 2	2 – 4	4 – 8	> 8
Soil toxicity	Depth of jarosite Reaction	Cm pH	>150 5.6 – 7.3	100 – 150 7.4 – 7.8 4.5 – 5.5	50 – 100 7.9 – 8.4 4.0 – 4.4	< 50 > 8.4 < 4.0
Flood hazard	Frequency	Yrs./time	10 Yrs./1	6-9 Yrs./1	3-5 Yrs./1	1-2 Yrs./1
Soil workability	Workability class topsoil	Class	1, 2	3	4	–
Mechanization	Slope Rockout crop Stoniness	% Class Class	0 – 2 1 1	2 – 5 2 2	5 – 20 3 3	> 20 4 4
Erosion hazard	Slope	Class	AB	C	D	> D

Source: LDD.

TABLE A4.2

Suitability Assessment Criteria for cassava

Factors			Suitability Assessment Criteria			
Attribute	Diagnostic	Unit	Very Suitable	Suitable	Moderately Suitable	Marginally Suitable
	Temperature	°C	>25	< 25	–	–
Moisture	Rainfall	Mm	1000 – 1500	1500 - 2500 900 - 1000	2500 - 4000 500 - 900	> 4000 < 500
Oxygen	Soil drainage	Class	5, 6	4	–	1, 2, 3
Nutrient availability	Nutrient status N P K Organic matter	Class % ppm Ppm %	VH, H, M > 0.1 > 10 > 30 > 1	– < 0.1 < 10 < 30 < 1	– – – – –	– – – – –
Nutrient retention	C.E.C. subsoil B.S. subsoil	meq/100g %	> 10 > 35	< 10 < 35	– –	– –
Rooting condition	Soil and Water depth Root penetration	Cm Class	> 100 1	50 – 100 2	25 – 50 3	< 25 4
Salt excess	EC. of saturation	dS./m	< 2	2 – 4	4 – 8	> 8
Soil toxicity	Depth of jarosite Reaction	Cm pH	>100 6.1 – 7.3	50 – 100 7.4 – 7.8 5.0 – 6.1	25 – 50 7.9 – 8.4 4.0 – 5.0	< 25 > 8.4 < 4.0
Flood hazard	Frequency	Yrs./time	10 Yrs./1	6-9 Yrs./1	3-5 Yrs./1	1-2 Yrs./1
Soil workability	Workability class topsoil	Class	1, 2	3	4	–
Mechanization	Slope Rockout crop Stoniness	% Class Class	0 – 12 1 1	12 – 23 2 2	23 – 38 3 3	> 38 4 4
Erosion hazard	Slope Soil loss	Class Ton/rai/yr	AB < 2	C 2 – 4	D 4 – 12	> D > 12

Source: LDD.

TABLE A4.3

Suitability Assessment Criteria for oil palm

Factors			**Suitability Assessment Criteria**			
Attribute	Diagnostic	Unit	Very Suitable	Suitable	Moderately Suitable	Marginally Suitable
	Temperature	°C	>29	25 – 29	22 – 25	< 22
Moisture	Rainfall	Mm	2000 - 3000	3000 - 4000 1800 - 2000	4000 - 5000 1500 - 1800	>5000 <1500
Oxygen	Soil drainage:					
	Trenching	Class	4, 5	3	2, 6, 7	1
	Non-trenching	Class	3, 4, 5	1, 2	–	–
Nutrient availability	Nutrient status	Class	VH, H, M	L	–	–
	P	ppm	> 45	15 – 45	10 – 15	< 10
	Organic matter	%	> 4.5	2.5 – 4.5	1.5 – 2.5	< 1.5
Nutrient retention	C.E.C. subsoil	meq/100g	> 15	3 - 15	< 3	–
	B.S. subsoil	%	> 35	< 35	–	–
Rooting condition	Soil depth	Cm	> 150	100 – 150	50 – 100	< 50
	Root penetration	Class	1, 2	3	4	–
Salt excess	EC. of saturation	dS./m	< 2	2 – 3	3 – 6	> 6
Soil toxicity	Depth of jarosite	Cm	>150	100-150	50-100	
	Reaction	pH	5.1-6.0	6.1-7.3 4.5-5.0	7.4-8.4 4.0-4.4	> 8.4 < 4.0
Flood hazard	Frequency	Yrs./time	10 Yrs./1	6-9 Yrs./1	–	3-5 Yrs./1
Soil workability	Workability class topsoil	Class	1, 2	3	4	–
Mechanization	Slope	%	0 – 12	12 – 23	23 – 38	> 38
	Rockout crop	Class	1	2, 3	4	5
	Stoniness	Class	1	2	3	4
Erosion hazard	Slope	Class	ABC	D	E	> E

Source: LDD.

TABLE A4.4

Return on investment analysis for crop type

Order	**Type**	**Benefit $/ton**	**Cost $/ton**	**B/C**	**Margin %**
1	Orange	419.7	193.0	2.17	217.46
2	Shallot	429.7	280.2	1.53	153.36
3	Rubber	1 500.1	1 182.2	1.27	126.89
4	Oil palm	62.9	68.8	0.91	91.45
5	Pepper	2 180.8	2 414.8	0.90	90.31
6	Irrigated rice	162.5	205.2	0.79	79.21
7	Corn	107.3	135.7	0.79	79.05
8	Soybean	220.5	323.7	0.68	68.12
9	Cassava	22.1	33.1	0.67	66.82
10	Pineapple	47.5	84.8	0.56	56.01
11	Coffee	623.9	1 208.5	0.52	51.63
12	Durian	148.7	484.6	0.31	30.68
13	Rainfed rice	77.5	259.5	0.30	29.85
14	Mung bean	78.6	473.8	0.17	16.59
15	Longkong	93.0	709.7	0.13	13.1
16	Longan	61.8	501.6	0.12	12.32
17	Sugar cane	2.0	19.4	0.10	10.41
18	Peanut	13.9	506.9	0.03	2.75
19	Potato	-0.55	267.7	0.00	-0.21
20	Garlic	-14.61	560.3	-0.03	-2.61
21	Rambutan	-47.89	338.9	-0.14	-14.13
22	Lychees	-191.64	666.5	-0.29	-28.75
23	Mangosteen	-272.18	645.7	-0.42	-42.16
24	Onion	-81.19	186.3	-0.44	-43.59

Source: LDD.

CHAPTER 5

NATURAL RESOURCE ANALYSIS: WATER

There is global consensus that the competition for scarce water resources is intense and that the world faces unprecedented challenges in using water sustainably (CA, 2007). Today, agriculture requires about 86 percent of the fresh water available worldwide (Hoekstra and Chapagain, 2007). In many parts of the world, agriculture has to compete for water with urban centres and industries (Falkenmark, 1997; Postel et al., 1996; UNESCO, 2006). Competition occurs where urban centres expand into formerly rural areas and water demand for households and industry grows, often leaving agriculture with insufficient water. There is also competition between upstream and downstream users. The large-scale introduction of biofuels to mitigate the effects of climate change may establish another competitor for water resources.

However, the current discourse pays limited attention on the effects of biofuel production on water use and on local water systems. More than 1.2 billion people already live in water scarce areas (CA, 2007). With increasing demand for irrigation from the domestic and industrial sectors, people at risk of water shortages will increase to one-third of the world's population by 2050 (de Fraiture et al, 2007). The stress on land and water resources could accelerate with increasing demand for biofuel.

This chapter assesses the effect biofuel production has on water, in particular the effect of molasses and cassava ethanol production. It is also an assessment of the effects of increasing biofuel demand due to the AEDP on local water systems in Thailand. The water footprint is a geographically explicit indicator because it depends on a location-specific set of factors such as hydrology, climate, geology, topography, agriculture management and yields. The water footprint for biodiesel was not assessed for the BEFS project.

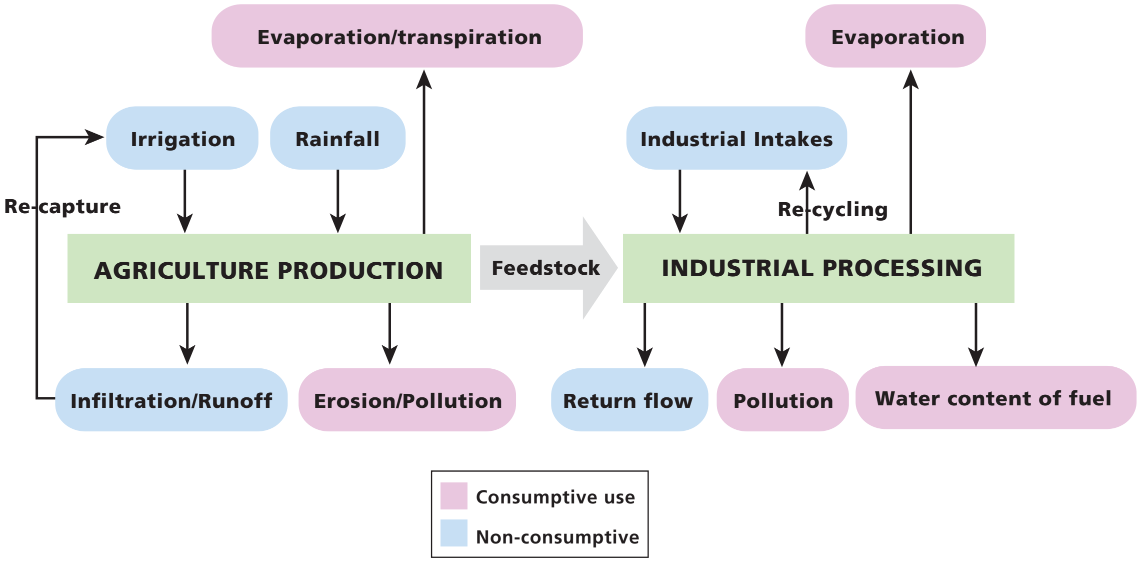
5.1 THE METHODOLOGY OF WATER FOOTPRINTS

The water footprint (WF) is a concept introduced to address the issue of freshwater used to produce the goods and services related to a certain consumption pattern. In the biofuel supply chain water is consumed in both the agricultural and industrial phases.

The WF has three components: green, blue and grey. The green component is the volume of rainwater that evaporates during the production process. It refers to the total evapotranspiration during crop growth from fields and plants. The blue component refers to the volume of surface and groundwater that evaporates during crop growth. It is defined as the sum of the evaporation of irrigation water from the field and the evaporation of water from irrigation canals and artificial storage reservoirs. In industrial production and services, the blue component is defined as the amount of water withdrawn from ground or surface water that does not return to the system from which it came. The grey component is the volume of water that becomes polluted during production. The grey component is defined as the amount of polluted water associated with the production of goods and services. It is the amount of water needed to dilute pollutants that enter into the natural water system during the production process to the extent that the quality of the ambient water remains above agreed water quality standards (UNESCO, 2008). The first two are related to water use, the latter to water pollution.

Water is used in the overall biofuel life cycle and its depletion can be distinguished in consumptive water use (CWU) and non-consumptive water use (N-CWU). CWU is water that has been used up permanently, e.g. depletion through evaporation and transpiration. N-CWU is the return flow of water that may or may not be captured for further use (Figure 5.1).

FIGURE 5.1
Land Suitability Assessment flowchart



Source: Fingerman et al, 2010.

This analysis estimates the total WF for sugar cane and cassava ethanol in terms of water depleted per unit of biofuel (m^3/litre) and total water depleted per year (m^3/year).

5.1.1 Water footprints of ethanol production

The WF for sugar cane, specifically molasses, ethanol will be estimated first and then the same process applied to cassava ethanol. Water depletion in ethanol production occurs in three stages (Figure 5.2): first, agricultural water use during sugar cane crop growth (A); second, industrial water uses in the production of sugar and molasses from sugar cane (B); and third, industrial water used in producing ethanol (C).

In the first stage, rainwater, which is stored in soil moisture, is one form of direct water use. Irrigation withdrawals, either through canal or groundwater, and wastewater application are other forms of direct water use. Seeds contribute to indirect water use. However, the quantity of water use in seeds is generally negligible compared to direct water use. In this stage water pollution occurs when fertilizer and pesticide leach into the groundwater or enter local river systems. At the crop production stage, the green WF is the minimum between effective rainfall and crop-specific evapotranspiration, in this specific case sugar cane. If the crop is irrigated, the blue WF is the net evapotranspiration requirement, which is the minimum between the difference of the crop-specific evapotranspiration and the effective rainfall and 0. In Appendix equations 5.1 and 5.2 define the green and blue WF for a generic crop.

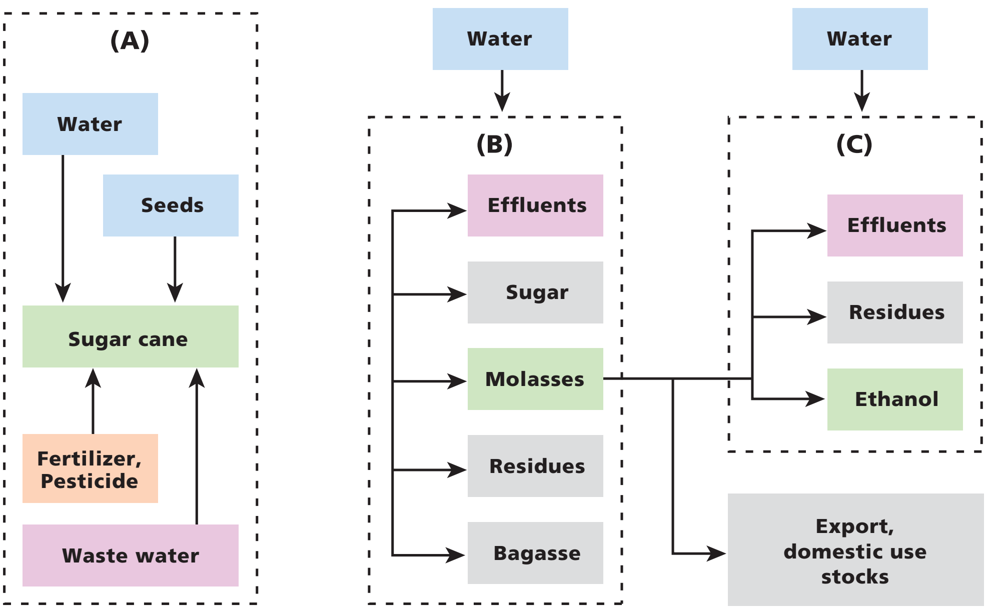
In the second stage, sugar cane is processed to obtain sugar as the main product, and molasses and bagasse as by-products (B in Figure 5.2). Thus, only a part of the sugar cane production WF can be attributed to molasses production. To estimate the coefficient of attribution the conversion rates and the export prices of sugar, molasses and bagasse are used. Moreover, direct water use in the industrial production process B is considered to contribute to the blue WF. Effluents generated in this process contribute to water pollution. In Appendix equations 5.3 and 5.4 define the green and blue WF for molasses.

In the third stage an industrial process converts molasses into ethanol (C in Figure 5.2). The green WF of ethanol is a share of the green WF of molasses, where the share is the conversion rate of molasses to ethanol. Industrial water use for producing ethanol is treated as blue WF. Technical details can be found in the equations 5.5 and 5.6 in Appendix. Also in this industrial process, the wastewater is the water polluter. Wastewater stored in ponds is first treated to bring its quality parameters to an acceptable level, and next reapplied to crop fields primarily as fertilizer. During this process, part of the wastewater stored in ponds can leach into groundwater systems, and part of the wastewater applied to fields can reach local river systems with rainfall or irrigation return flows.

The estimation of WF of cassava ethanol is similar to that of sugar cane, except that there is only one stage of industrial production. First, water use is in cassava production. Next, a part of the cassava production is directly used for ethanol production and the rest for food and feed use. In Appendix equations 5.1 and 5.2 estimate the green and blue WF of cassava crop production; equations 5.5 and 5.6 estimate the green and blue WF for the process of converting cassava to ethanol.

FIGURE 5.2

Process of sugar-based ethanol production



Notes: A – Sugar cane production; B – Sugar/molasses production; C – Ethanol production.

5.2 WATER FOOTPRINTS OF ETHANOL PRODUCTION IN THAILAND

5.2.1 Data and assumptions

The FAOSTAT national and sub-national (FAO, 2010a & b) databases are the source for sugar cane and cassava area and production. The Water and Climate Atlas of the International Water Management Institute (IWMI, 2000) was the source of evapotranspiration. The crop coefficients and the lengths of the growing periods (initial, development, mid-season and late-season) of sugar cane and cassava are taken from the AQUASTAT database (FAO, 2010c).

Water and other input use in crop and ethanol production processes are assessed using a rapid survey. For crop production, five farmers in Baan Pong district (Rajburi province) and five farmers in Chaibadan district (Lopburi province) were interviewed. For the industrial process, the information was collected at the Rajburi sugar factory, the Thai Sugar ethanol plant in Kanchanaburi province and the Sapthip ethanol plant in Lopburi.

The assumption made in estimating the WF of crop production and industrial production of sugar, molasses and ethanol are given below:

- The analysis uses average export prices from 2007 to 2009 for sugar ($277) and molasses ($75) (FAO, 2010a);
- One ton of sugar cane produces 0.045 ton of molasses and 0.11 ton of sugar (FAO, 2010a);
- One litre of ethanol requires four kg of molasses or 5.88 kg of cassava (DEDE, 2010); and
- In the first industrial process related to sugar cane, water is used for cleaning the sugar cane, for juice extraction and for concentration. It is estimated that these steps require 1.22 m^3/ton of sugar cane. The water requirement is again divided using export prices of sugar, molasses and bagasse. The second industrial process mainly requires water for fermentation and distillery. This is assumed to be 8.72 m^3/ton of molasses (Moreira, 2009).

5.2.2 Water footprint of sugar-based ethanol

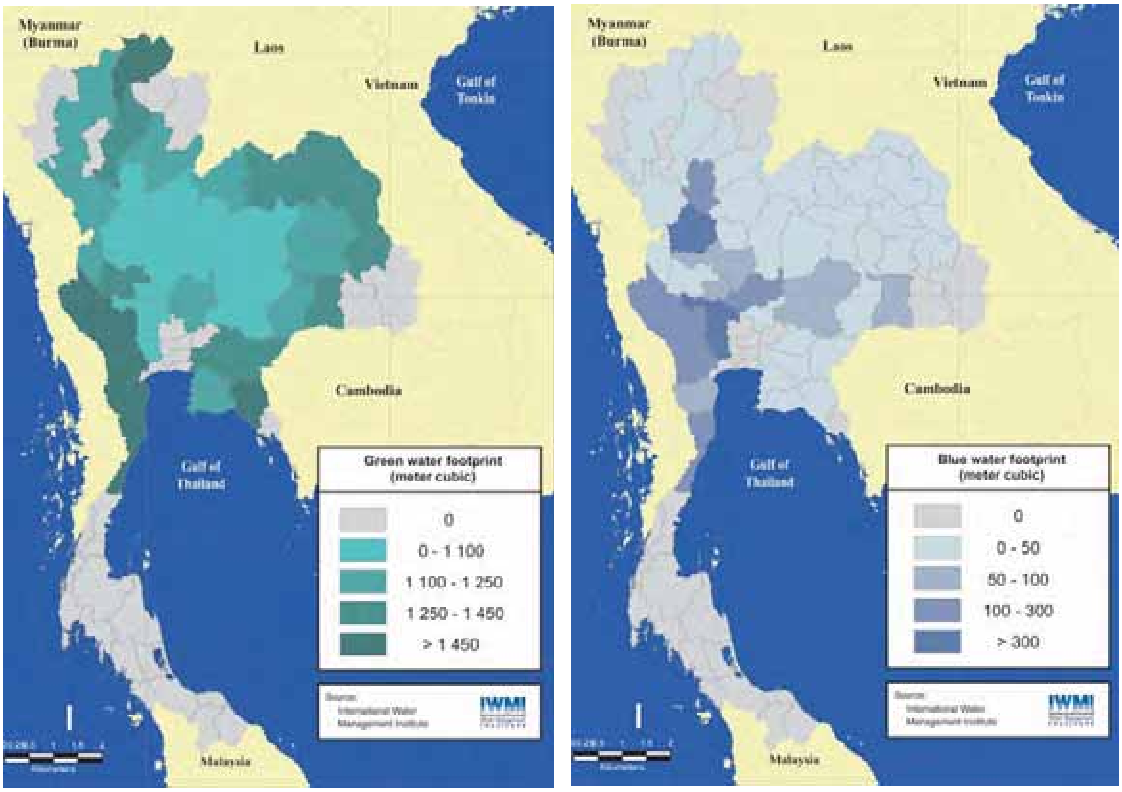
Although effective rainfall meets 57 percent of the crop's water requirements or potential crop evapotranspiration of sugar cane, only 14 percent of the sugar cane plantations are irrigated. In 2004-2006, the average harvested area of sugar cane was 1.047 million hectares.

The total green and blue WF of sugar cane, molasses and molasses-based ethanol are 146, 322 and 1 646 m^3/ton respectively. Alternatively, 1 299 litres of water is consumed during the complete production cycle of one litre of ethanol from molasses. Effective rainfall contributes 90 percent of the total WF of sugar cane production, and 89 percent in molasses ethanol production. This slight reduction is due to water withdrawn for industrial uses. The water consumed in the industrial processes in sugar mills and ethanol production plants — 12.7 litres of water for one litre of ethanol —accounts only nine percent of the total blue WF of 140 litres for one litre of ethanol.

If the sugar cane for ethanol is produced in different districts, then WF could vary from 985 to 2 111 litres of water for one litre of ethanol across districts (Figure 5.3). With 70 percent of the total irrigated area, the central provinces contribute largely to the blue WF, followed by the Northern provinces, which have 26 percent of the total irrigated area.

FIGURE 5.3

Sugar-based ethanol WF by districts



Source: IWMI.

5.2.3 Water footprints of cassava-based ethanol

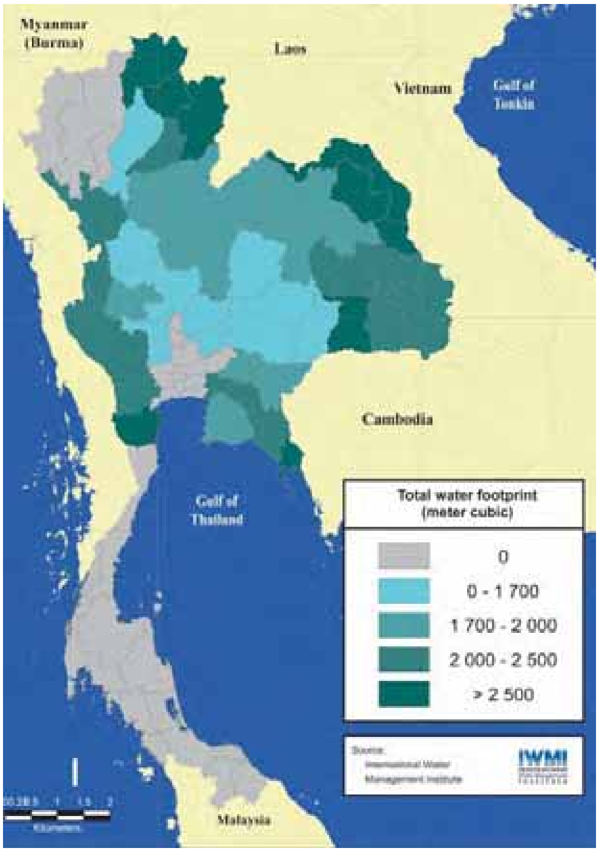
Cassava is the main crop for future ethanol production foreseen in the AEDP. In Thailand, it is mainly a rainfed crop. Effective rainfall share in the evapotranspiration of cassava is 81 percent and no area is irrigated at present. The harvested area under cassava in 2004-2006 was 1.05 million hectares.

The total of green and blue WF of cassava and cassava ethanol production are 307 and 2 304 m^3/ton respectively. Alternatively, 1 817 litres of water is consumed during the complete production cycle of one litre of ethanol from cassava. The blue WF is comprised only of the industrial processes. The calculated blue WF is 12.3 litres for one litre of ethanol.

The WF of cassava ethanol varies from 1 265 to 3 070 litres of water per one litre of ethanol across provinces (Figure 5.4), due to the large variation in cassava yields. Across districts, the evapotranspiration of cassava varies from 726 to 914 mm, while yields vary from 14.0 to 31.5 tons/ha.

FIGURE 5.4

Cassava-based ethanol WF by districts



Source: IWMI.

In terms of blue WF, cassava provides a better feedstock than molasses for ethanol production. While rainfall contributes to almost all the WF of the cassava ethanol production, irrigation meets a part of the water requirement in molasses ethanol production.

5.2.4 Future trends of biofuel water footprint

As discussed previously, Thailand projects cassava to be the main feedstock for future ethanol production. Currently, molasses contributes 50 percent of the ethanol production, and this share is expected to decrease to 20 percent by 2018 and remain at that level thereafter.

In 2007-2009, Thailand produced on average 67.8 million tons of sugar cane and consumed 9.9 billion m^3 of water with a 989 million m^3 from irrigation. The blue WF of sugar cane production is only 0.2 percent of the 444 billion m^3 of total renewable water resources (TRWR) in Thailand. More than 70 percent of the blue WF is concentrated in four districts of Kamphaeng Phet province in the north (33 percent) and in three provinces in the central region, namely Suphan Buri (19), Nakhon Pathom (17), Kanchanaburi (7). The proportion of the blue WF when compared to the internal renewable water resources of each of these four locations is four, 13, three and one percent respectively.

Based on the AEDP ethanol targets, ethanol production from molasses is estimated to consume 500 million m^3 of water in 2010. The blue WP in the ethanol production process from molasses is only 0.01 percent of the TRWR. At the rate of current water consumption, the total WP of sugar-based ethanol could reach 853 million m^3 by 2022, including 11 percent from irrigation. The blue WF of sugar-based ethanol will still be only 0.2 percent of the TRWR.

However, this scenario may change due to the projected yield increase. To meet the increasing ethanol demand, Thailand projects the sugar cane yield to increase to 93.8 ton/ha by 2012, from the current level of 53.5 ton/ha in 2006 (DEDE, 2010). If such an increase in sugar cane yields is going to occur, the total irrigated area and hence evapotranspiration from irrigation would inevitably increase. This means higher blue WF and consequently total WF. Since irrigation water consumption in the crop production constitutes the major part of sugar-based ethanol WF, only the sugar cane production WF is considered here.

Three scenarios were tested: a ten, 20 and 30 percent increase in the irrigated area under sugar cane plantation. Detailed information is reported in Table 5.1.

In the absence of information about other inputs, it is assumed that a ten percent increase in sugar cane irrigated area could result in three different yield scenarios; namely possible increases 1.6, 3.2 and 4.8 percent. Under this scenario, the WF of one ton of sugar cane will increase to between 145 to 154-149 m^3 of water. The total blue WF of sugar cane production shall be only 0.3 percent of the TRWR.

A 20 percent increase in total irrigated area is assumed to result in possible yield increases of 3.2, 6.4 and 9.6 percent. Under this scenario, the WF of one ton of sugar cane will increase to between 162-147 m^3/ton. The total blue WF is about 0.43 percent of TRWR.

A 30 percent increase in total irrigated area is assumed to result in possible yield increases of 4.8, 9.6 and 14.4 percent. Under this scenario, the sugar cane WF will actually fall below the base scenario. The total blue WF will reach 0.56 percent of the TRWR.

TABLE 5.1

Sugar cane WF under scenarios of irrigated area and yield growth

Scenarios	Sugar cane irrigated area	Sugar cane yield increase	Sugar cane yield	Sugar cane WF
	% of the total	%	Ton/ha	m^3/ton
Base	14	–	51.46	146
SC1	24	1.6	52.29	154
		3.2	53.11	151
		4.8	53.93	149
SC2	34	3.2	53.11	162
		6.4	55.63	154
		9.6	58.21	147
SC3	44	4.8	56.52	161
		9.6	58.21	157
		14.4	63.64	143

Source: IWMI.

These scenarios show that sugar-based ethanol production, and for that matter even the total sugar cane production, shall consume only a small part of the TRWR. However some concerns need to be addressed to realize the AEDP targets of sugar-based ethanol production in the near future.

The scenarios show the corresponding increase in the sugar cane yield due to the simulated expansion of the irrigated area. The yields calculated fall far short of the yield projections envisioned in the AEDP up to the year 2012. The gap between the irrigated and rainfed sugar cane yields indicates that achieving the growth in yields required to meet the short-term AEDP targets may not be possible; even with substantial growth in irrigated area.

The scenario analysis demonstrates that to improve sugar cane yield more irrigation is necessary. To achieve a 10-30 percent increase in irrigated area will require increased irrigation withdrawals of between 76-222 percent. Realizing this type of growth in the short-term will present a significant challenge.

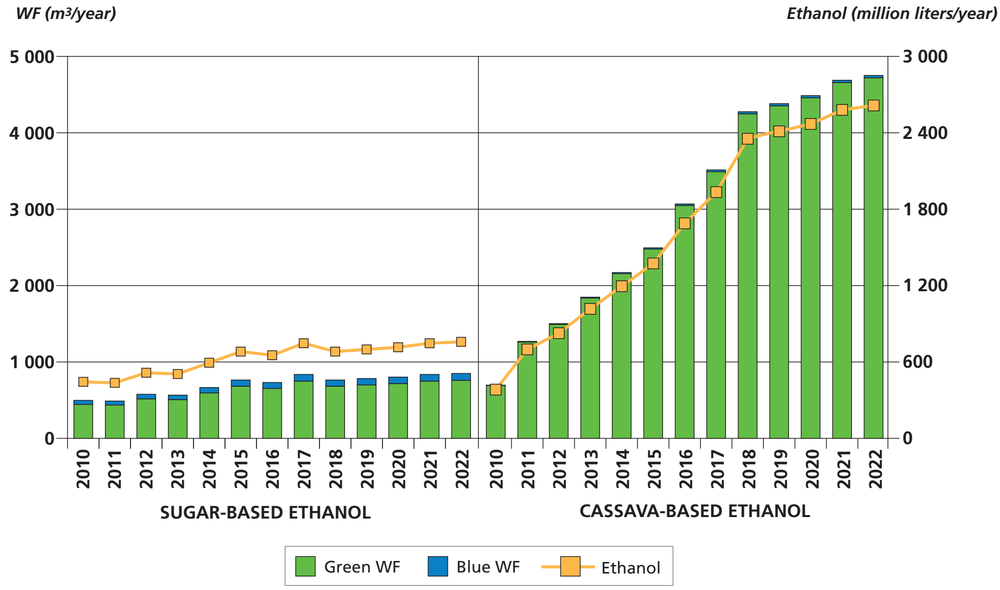
An alternative to new irrigation is reallocation of irrigation from other crops. The other major irrigated crop in Thailand is rice. At present 26 percent of ten million hectares annual rice cropped area is irrigated. A total WF of rice is 1 621– 1 456 m^3/ton from soil moisture and 165 m^3/ton from irrigation. This shows that forgoing one ton of rice could provide irrigation to produce at least ten tons of sugar cane. With 2.56 tons/ha of average rice yield, water consumed in one hectare of rice land could provide irrigation to increase sugar cane production by an additional 20-30 tons. Thus, it seems that reallocation of water from rice to sugar cane production is a possible option for providing the irrigation to increase sugar yields. However, such action may create additional risks to food security.

In the case of cassava ethanol the total WF is 710 million m^3 in 2010. The contribution of the blue WF –15 million m^3 – is negligible in comparison to TRWR. As per the government plans, cassava is expected to be the feedstock for 80 percent of ethanol demand by 2022. At the current rate of WF, the total cassava ethanol WF is expected to reach 4 846 million m^3 by 2022 or one percent of TRWR. Most of it –97.9 percent– is expected to come from effective rainfall. As can be seen in Figure 5.5, unless there is a substantial increase in crop yield or reduction in cassava exports over this period, rainfed crop lands under cassava will have to be increased significantly to meet future ethanol demand.

If cassava exports and area under production is going to remain at the present level, the yield of cassava needs to increase by at least six times to meet anticipated demand for cassava feedstock.

FIGURE 5.5

Total WF of sugar and cassava-based ethanol



Source: MoE.

5.3 WATER QUALITY IMPACTS ON LOCAL WATER SYSTEMS

In addition to withdrawing water from water systems, ethanol production can also affect the water quality of these systems.

Urea fertilizer is a major source of nitrogen leaching into groundwater. In Thailand, sugar cane and cassava production uses about 260 and 200 kg/ha of fertilizers (Table 5.2), but this varies significantly across farms. The nitrogen application alone varies from 65 to 120 kg/ha.

TABLE 5.2

Chemical fertilizer and other inputs for sugar cane and cassava

		Sugar cane	Cassava
Fertilizer (kg/ha)	N	90	90
	P	60	50
	K	110	60
	Total	260	200
Fungicide (kg/ha)		–	620
Insecticide (kg/ha)		60	–
Herbicide (L/ha)		800	–

Source: IWMI based on farm level surveys.

The fertilizer application in sugar cane and cassava crop production currently leaches about 8 680 tons of nitrogen load to groundwater aquifers. Thus, the amount of water required to eliminate the deterioration of water quality during the process of crop production is equivalent to 0.868 billion m^3. However, this is only a small fraction (two percent) of the annual groundwater recharge of 41 billion m^3 at present.

Wastewater generated in mills and ethanol plants is the biggest contributor to water quality deterioration during ethanol production. In sugar-based ethanol production the liquid effluents are molasses and wastewaters. For example, the Rajburi sugar mill generates about 1 500-2 000 m^3 of wastewater per day and produces 650 tons of molasses; Sapthip ethanol distillery generates 1 600 m^3 of wastewater and produces 400-450 tons of molasses per day. A substantial amount of the wastewater, called spent wash, is stored in ponds. The spent wash has high potential for water pollution (Table 5.3). The spent wash generated at the distillery plants is acidic (pH 4.5), has a very high temperature (65-70 °C), contains about 232-1 600 milligrams per litre (mg/L) of nitrogen and has a high content of biochemical and chemical oxygen (43 000 and 80-100 000 mg/L respectively), suggesting a large quantity of organic matter in spent wash. Another 74 000 mg/L of suspended solid are also recorded.

TABLE 5.3

Characteristics of spent wash from sugar and cassava-based ethanol

Parameter	Unit	Spent wash	
		Sugar-based ethanol	Cassava-based ethanol
pH	–	4.5	4.5
Temperature	°C	70	65
Biochemical oxygen	mg/L	n/a	43 000
Chemical oxygen	mg/L	80 000 -100 000	90 000
Total solids		~23% weight	74 000
Organic material	mg/L	n/a	1 600
Total Carbon	mg/L	n/a	n/a
Total Nitrogen	mg/L	232	1 600
Total Phosphorous	mg/L	62	n/a
Total Potassium	mg/L	1 383	n/a

Since Thailand has a zero discharge policy in its wastewater regulation, no direct discharge of wastewaters occurs from the factories into the water systems. Typically, an anaerobic treatment method and infiltration are used for wastewater treatment. Although treatment avoids the negative effect of direct discharge, there is a risk for soil and water pollution in the neighbouring area. High organic loads in these effluents can easily permeate through soil, particularly in areas with high distribution of sandy soil.

According to discussions with factory managers, the infiltration rate of wastewater in storage ponds at Rajburi Distillery is high. Typically it takes a few months for wastewater in a pond (about three to four meters deep, 30 to 40 meters wide) to dry. This is due to the fact that the soil texture in this area is sand and silty. It is well recognized that the coefficient of permeability (k) of sand is higher than that of silt and clay, which means water can penetrate through sand faster than silt and clay. The coefficient of permeability of sand ranges from 1 to 10-5 cm per second, while silt and clay range from 10-5 to 10-9 cm per second. It has been reported that in the area where soil textures are sand and salty sand, wastewater from the pond at the wastewater treatment plant can permeate for about 16 metres within five years. As already noted, some wastewater treatment plants are within one kilometer distance from the Mae Klong river, the surface water supply for people who live in Nakorn Pratom, Rajburi, and Khanchanaburi provinces. Therefore, there is a high risk of soil, surface and ground water contamination in this area.

Spent wash from ethanol distillation, with considerable plant nutrient, is widely used by cane growers with fields closer to sugar mills. According to interviews with farmers, ethanol spent wash is blended with other plant nutrients at 800 TBH per tank with a capacity of 12 m^3 and a 12 m^3 per tank of spent wash mixtures can be used in an area of about 0.6 - 0.8 ha. Spent wash mixture as liquid fertilizer is cost effective and was found to have increased cane yields to a satisfactory level.

It is well known that the application of spent wash, produced in ethanol and liquor distilleries, to agricultural land improves a range of soil properties. These include chemical (carbon, nitrogen and K contents, and nutrient holding capacity) and physical (water stable aggregates, hydraulic conductivity and soil water retention), resulting in enhanced crop productivity. However, evidence of the effect of spent wash application as a fertilizer on crop productivity growth in Thailand is scarce.

Currently, research is being carried out by government departments to assess the impact on soil and ground after applying spent wash. It was proved that the addition of liquor spent wash improves physical and chemical properties of soil and thus crop productivity (LDD, 2000). Similarly, research from Ramkumhang University indicates that applying spent wash from a liquor distillery at the rate of 60 m^3 combined with chemical fertilizer of 20-20-0 at 150 kg/ha of N-P-K per ha significant increased sugar cane yield up to 203 ton/ha in the first year, while applying 20-20-0 alone at 500 kg of a mean formula of N-P-K per ha yielded 75-94 kg/ha. The LDD report recommends applying combined applications of liquor spent wash at 125 -188 m^3/ha and chemical fertilizer of 16-20-0 at 70 kg of a mean formula of N-P-K per hectares for rice cultivation in northern Thailand.

On the other hand, negative effects have also been recorded. Applying liquor spent wash at a rate of more than 250 m^3/ha could result in soil salinity and nutrient imbalance and thus decrease crop productivity. Further research undertaken at the Chulalongkorn University in 2003 to 2004 shows that spent wash can contaminate soil and water with high organic carbon loads (BOD, COD and TOC) — soil and groundwater in surrounding areas of the storage pond at a depth of 20 meters, and surface water bodies at 100 meters away from the pond.

Although the quantity of spent wash generated at present is small, it can increase substantially in the future with more biofuel production. By 2022, the total wastewater generated from sugar-based ethanol would be at least 7.89 million m^3. Given the relatively small area of land currently under sugar-cane cultivation, it would be difficult to use such a quantity of wastewater as fertilizer. Thus storing the remaining wastewater/spent wash in ponds would be an enormous task, and, if stored, its effect on groundwater and surface water systems in and around mills and plants could be very damaging. The actual effects of stored spent wash on local water systems, especially on groundwater, need further assessment.

5.4 CONCLUSIONS

- *The ethanol industry in Thailand uses a relatively small amount of the country's total water resources*. In Thailand sugar cane (i.e. molasses) and cassava are the main feedstocks for ethanol production. The WF of sugar cane, molasses and molasses ethanol in Thailand are 145, 322, and 1 646 m^3/tons, respectively. The blue WF constitutes nine percent of the total WF of sugar-based ethanol. In terms of water use for irrigation, cassava is the better feedstock for ethanol production. Every litre of sugar-based ethanol requires 140 litres of water for the irrigation, while that from cassava requires only 12 litres. Based on ethanol production in 2010 the total blue WF is 69 m^3 and it represents only 0.02 percent of Thailand's TRWR. The WF of cassava and cassava ethanol are 307 and 2 304 m^3/ton respectively, where the blue WF constitutes only 0.7 percent of the total WF of cassava ethanol, mainly related to ethanol processing.
- *Thailand should have sufficient water resources to meet the anticipated expansion of ethanol with the AEDP targets*. At the rate of current water consumption, the total WF of sugar-based ethanol could reach 853 million m^3 by 2022, which represents only around 0.2 percent of Thailand's TRWR. At the current rate of WF, the total cassava ethanol WF is expected to be greater and reach around 4 846 million m^3 by 2022 or one percent of TRWR. However, to meet the feedstock requirements implicit in the AEDP targets, either substantial increases in irrigation or expansion of sugar cane and cassava under rainfed agriculture is required.
- *However, to achieve the improvements in the yield of sugar cane and cassava required by the AEDP irrigation of both crops will need to expand rapidly, which could present challenges in the short-term*. Biofuel demand and production is increasing in Thailand. Ethanol demand in Thailand is set to increase dramatically from 2.1 to nine MLPD, between 2010 and 2022. In the absence of a significant growth in area, a significantly high increase of the yields is the only solution. Given the difference in crop yields between districts and between irrigated and rainfed areas, the planned growth in yields for biofuels crops may not be a realistic goal without expanding biofuel crops under irrigation.
- *While the expansion of ethanol production is not expected to strain water resources in terms of volume, it may have serious impact on water quality near processing facilities*. Biofuel production processes generate a large quantity of wastewater including highly toxic spent wash. Although zero discharge of effluents is the government policy, spent wash is stored in a pond for a long period of time. This can have a significant negative effect on the local groundwater systems and subsequently on the neighbouring streams.

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5.6 APPENDIX

Here below are reported the equations for the definition of the green and blue WF.
For a generic crop, in the specific case sugar cane and cassava:

$$WF^{Green}_{Crop} = Minmun\ (EffRF,\ Et_c) \qquad (5.1)$$

$$WF^{Blue}_{Crop} = Minmun\ (Et_c - EffRF, 0) \qquad (5.2)$$

where:

WF^{Green}_{Crop} is the green WF.

WF^{Blue}_{Crop} is the blue WF, if irrigation occurs.

$EffRF$ is the effective rainfall.

Et_c is the crop-specific evapotranspiration.

The Et_c of a crop is estimated as the total of crop water requirements in four crop growth periods (initial, development, mid- and late stage). Crop water consumption is estimated by calculating Et_c using the Penman–Monteith model developed by FAO (1998). Et_c is the product of a reference crop evapotranspiration (Et_0) and a crop-specific coefficient (K_c). Et_0 characterizes climate effects and is calculated from temperature, solar radiation, wind speed, and relative humidity. K_c accounts for the effect of characteristics such as crop height, surface coverage, and albedo that distinguish a crop from the reference surface. In the specific case of this analysis the crop is sugar cane.
The green and blue WF for molasses production are estimated by equation 5.3 and 5.4.

$$WF^{Green}_{Molasses} = \beta\left(\alpha\ WF^{Green}_{Sugarcane}\right) \qquad (5.3)$$

$$WF^{Blue}_{Molasses} = \beta\left(\alpha\ WF^{Blue}_{Sugarcane} + WF^{Industrial}_{B}\right) \qquad (5.4)$$

where:

$$\alpha = \frac{q_2 p_2}{q_1 p_1 + q_2 p_2 + q_3 p_3}$$

$$\beta = \frac{1}{q_2}$$

with $q_1 p_1 + q_2 p_2 + q_3 p_3$ and $p_1 + p_2 + p_3$ respectively the conversion rates and the export prices ($/ton) of sugar, molasses and bagasse respectively;
The green and blue WF of ethanol are estimated using equation 5.5 and 5.6. Feedstocks in the specific case are molasses and cassava.

$$WF^{Green}_{Ethanol} = \gamma\left(WF^{Green}_{Feedstock}\right) \qquad (5.5)$$

$$WF^{Blue}_{Ethanol} = \gamma\left(WF^{Blue}_{Feedstock} + WF^{Industrial}_{C}\right) \qquad (5.6)$$

Where γ is the conversion factor for molasses into ethanol and $WF^{Industrial}_{C}$ is the water used per every ton of molasses used in the process of converting.

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.

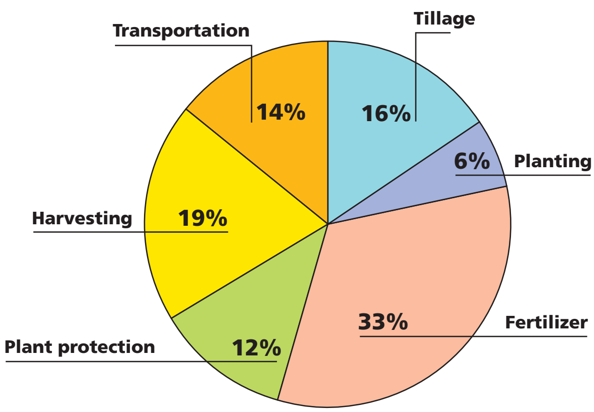
Figure 6.1 presents the average cost structure of farms assessed for the field survey. Here it can be seen that roughly 33 percent of total costs are related to purchasing, transporting and distributing fertilizer, whether mineral/chemical fertilizer or organic. The most common form of organic fertilizer 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

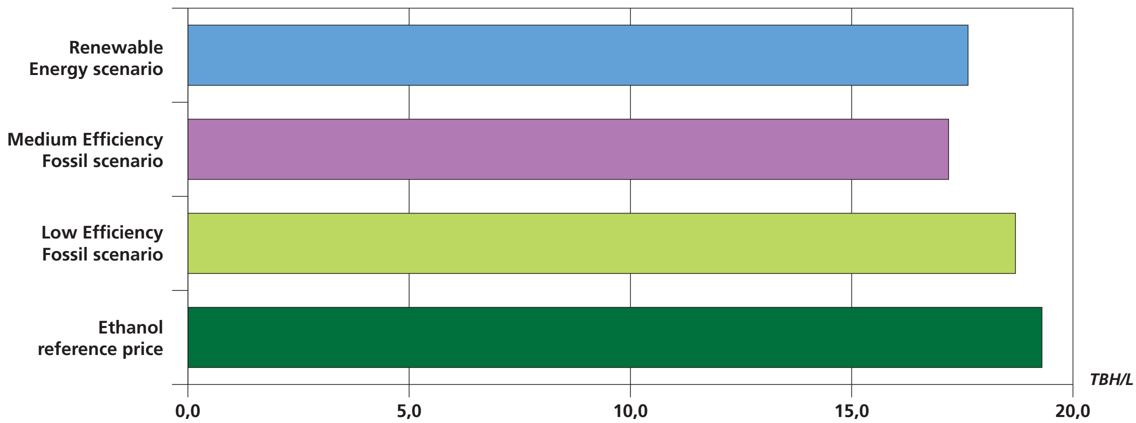
Source: JGSEE.

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

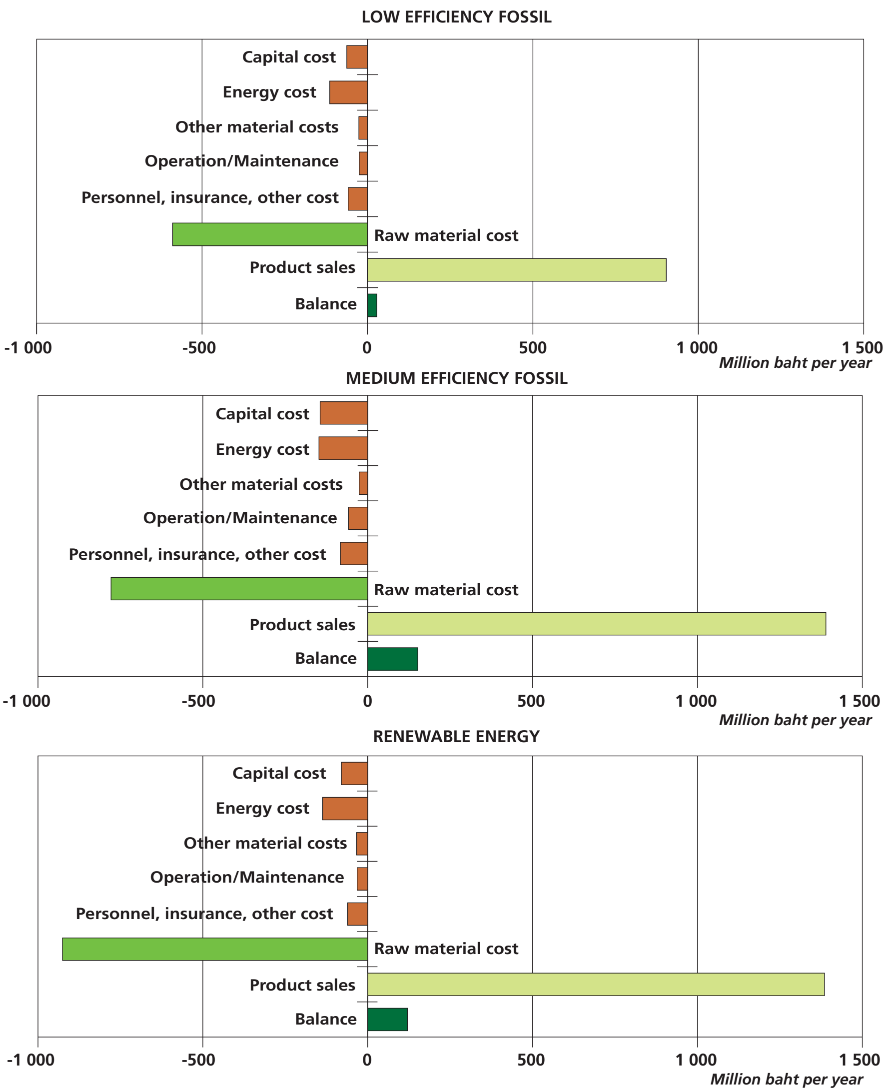
Source: JGSEE.

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

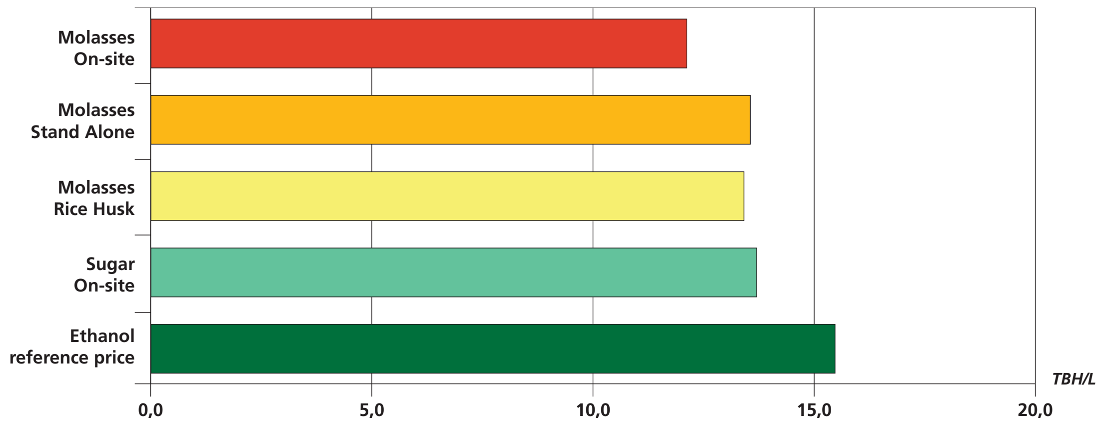
Production cost and IRR for sugar-based ethanol scenarios

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

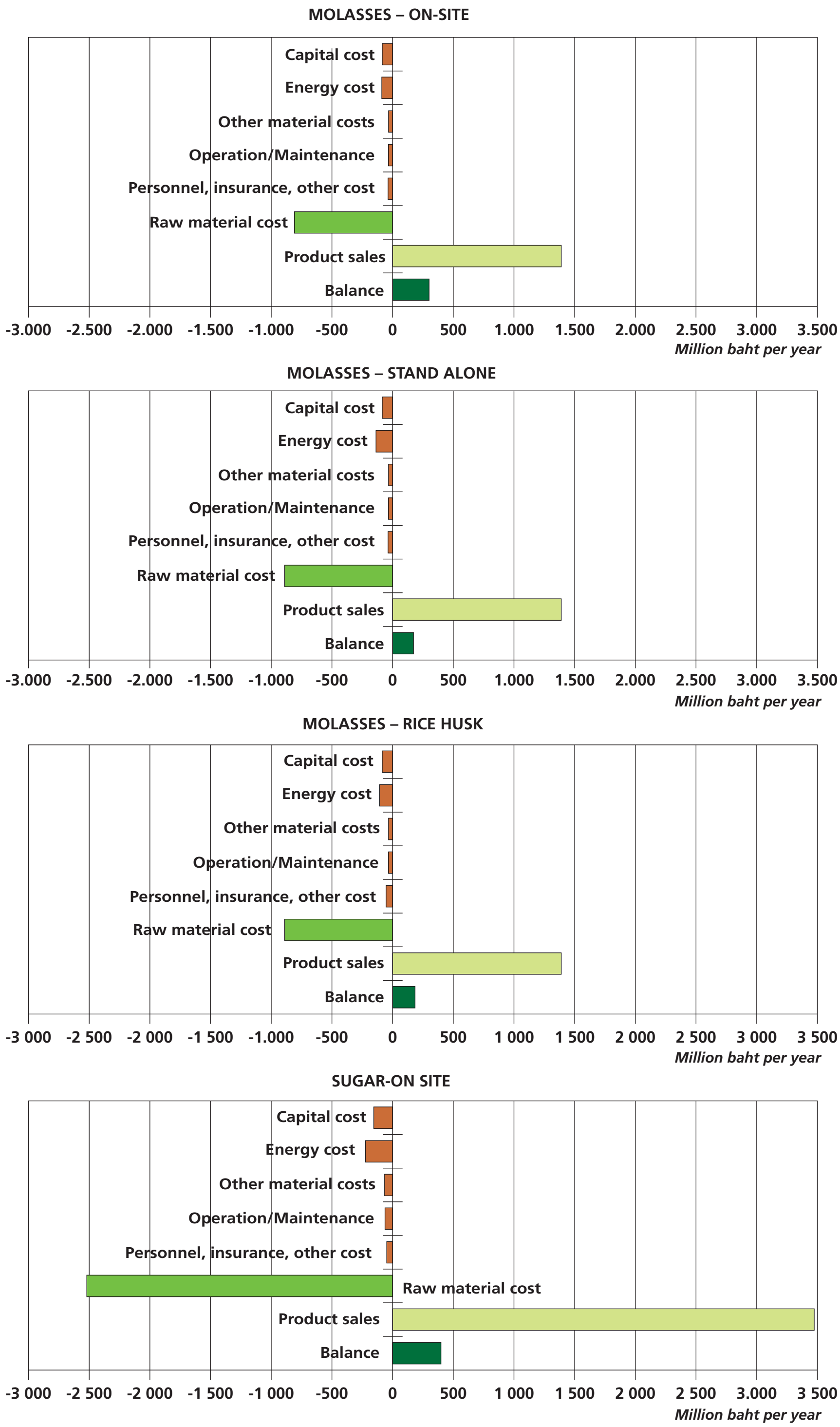
Comparison of sugar-based ethanol production costs



Source: JGSEE.

FIGURE 6.5

Cost and benefit summary for sugar-based ethanol scenarios



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

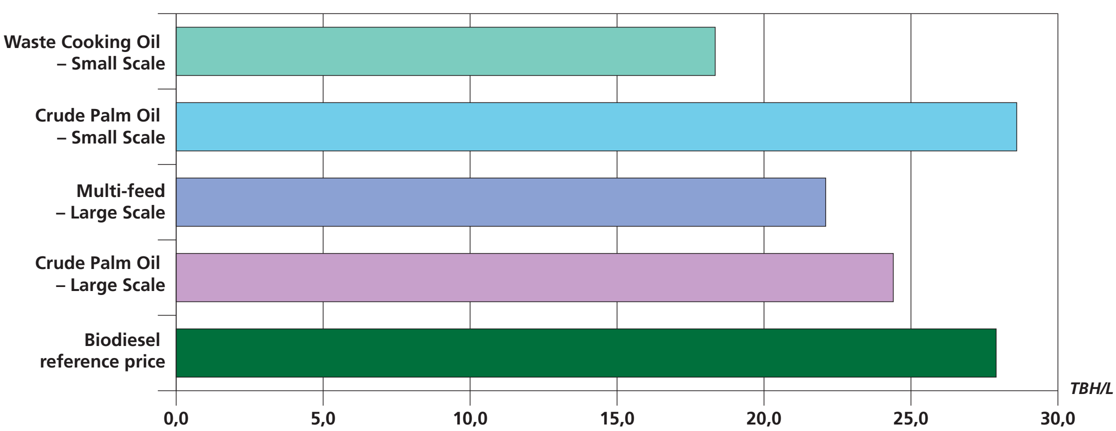
Characteristics of biodiesel configurations

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

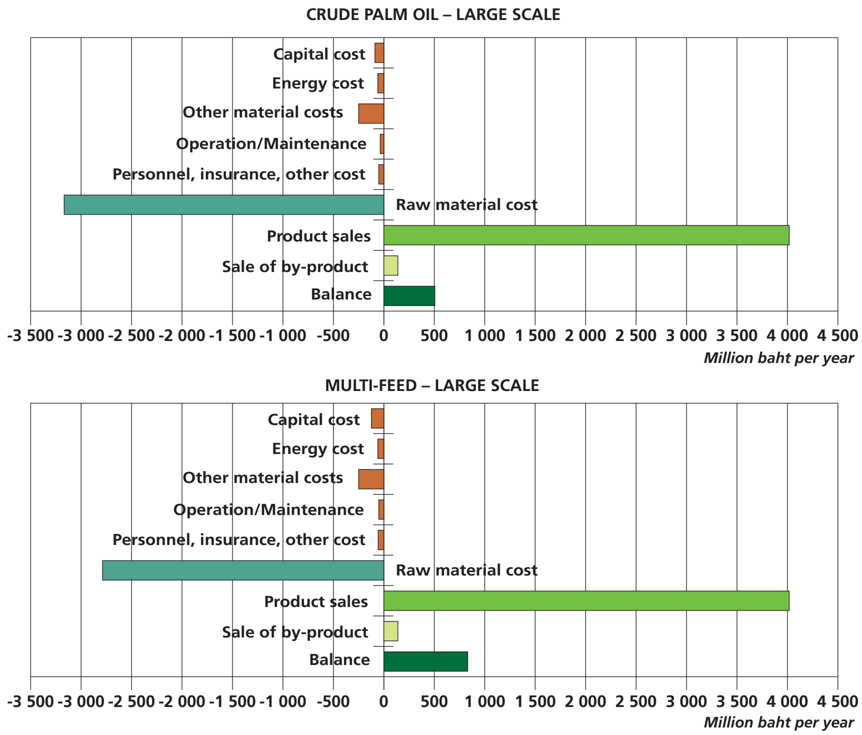
Production cost and IRR for biodiesel scenarios

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

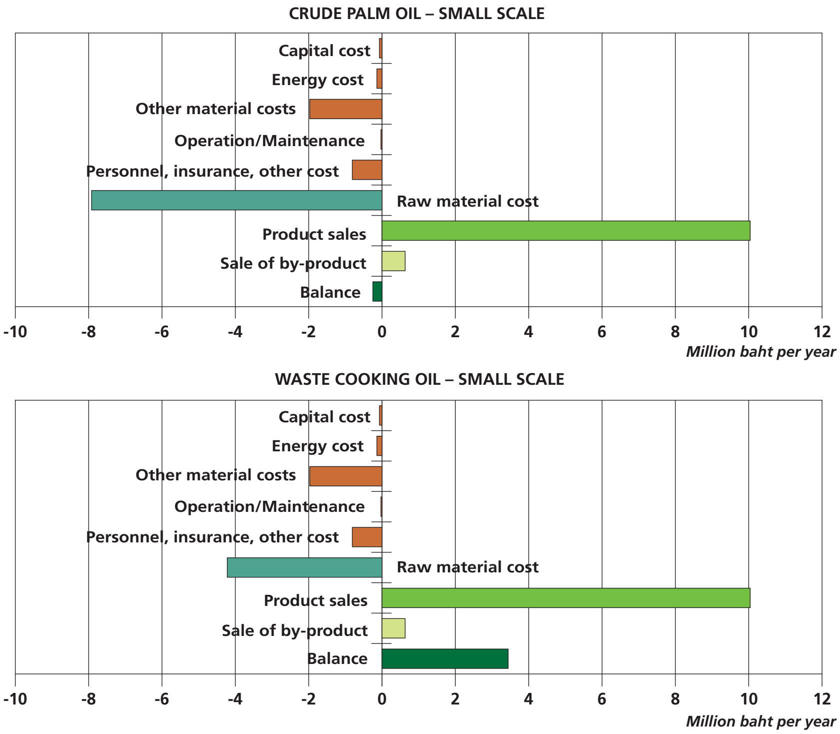
Cost and benefit summary for large scale biodiesel scenarios



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.

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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 *average case*	6.93	76.69	37.01 *12.21*	45.02	-25.69
Medium input level *average case*	5.43	50.00	24.65 *8.79*	29.76	-15.41
High input level *average case*	10.87	42.96	24.71 *13.30*	28.39	-4.14

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

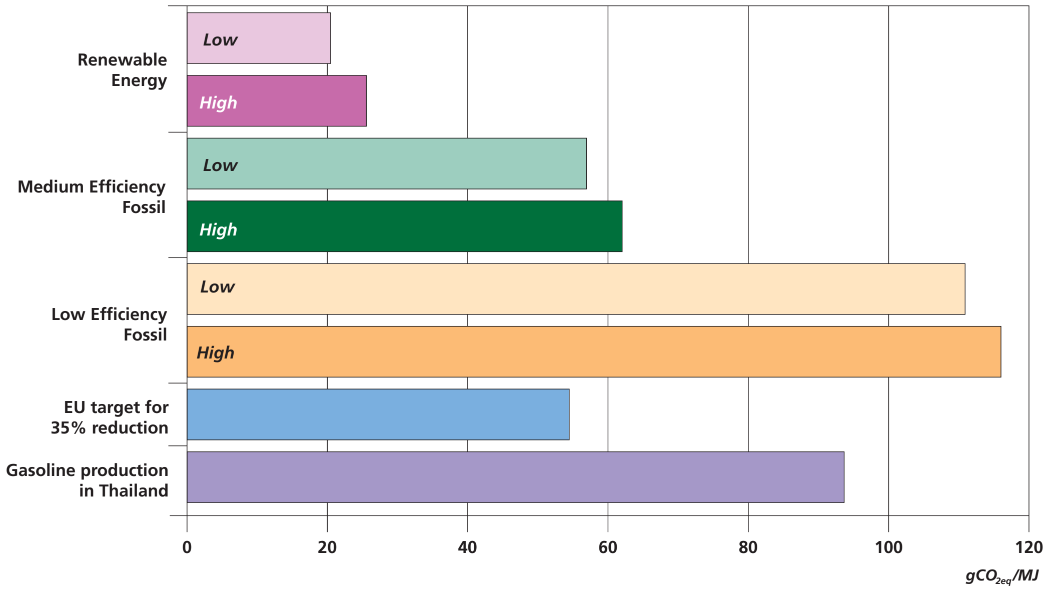
Ethanol production configuration	Level of inputs	Emissions						Energy requirement	
		CO_{2eq}	CO_2	CH_4	N_2O	SO_{2eq}	TOPP	Non RE	Renewable
		g/MJ	g/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	MJ/MJ	MJ/MJ
Low Efficiency Fossil	Low	110.90	108.11	16.41	8.16	1035.56	228.82	1.216	1.307
	High	116.01	109.26	20.80	21.18	1048.31	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.

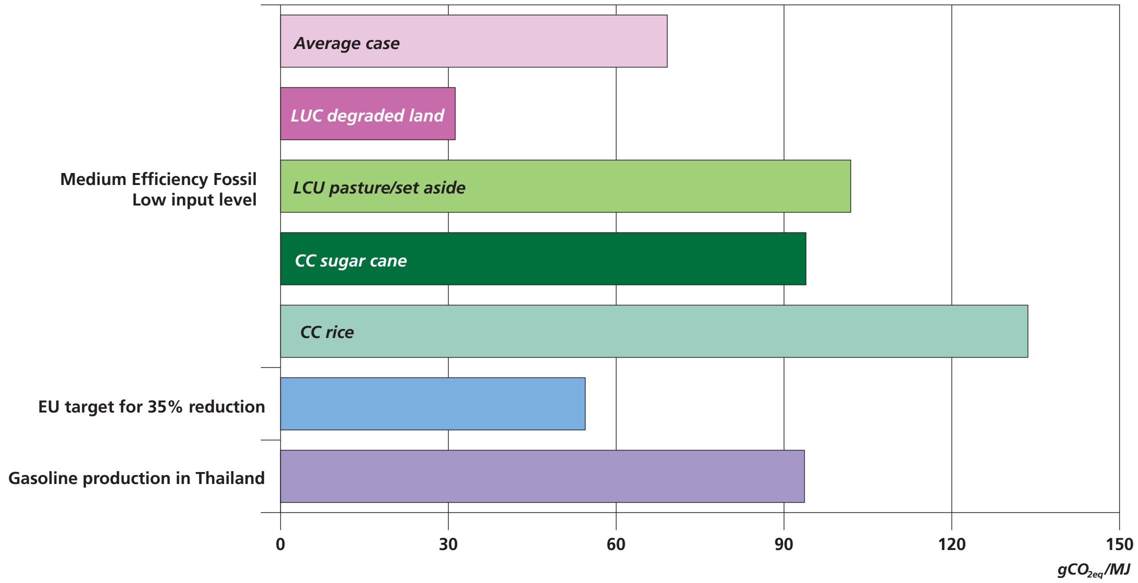
To understand how LUC and CC might affect cassava ethanol's performance against the EU sustainability criteria, LUC and CC scenarios were integrated into the medium efficiency fossil and renewable energy production configurations with low level inputs in cassava production. The results for both configurations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

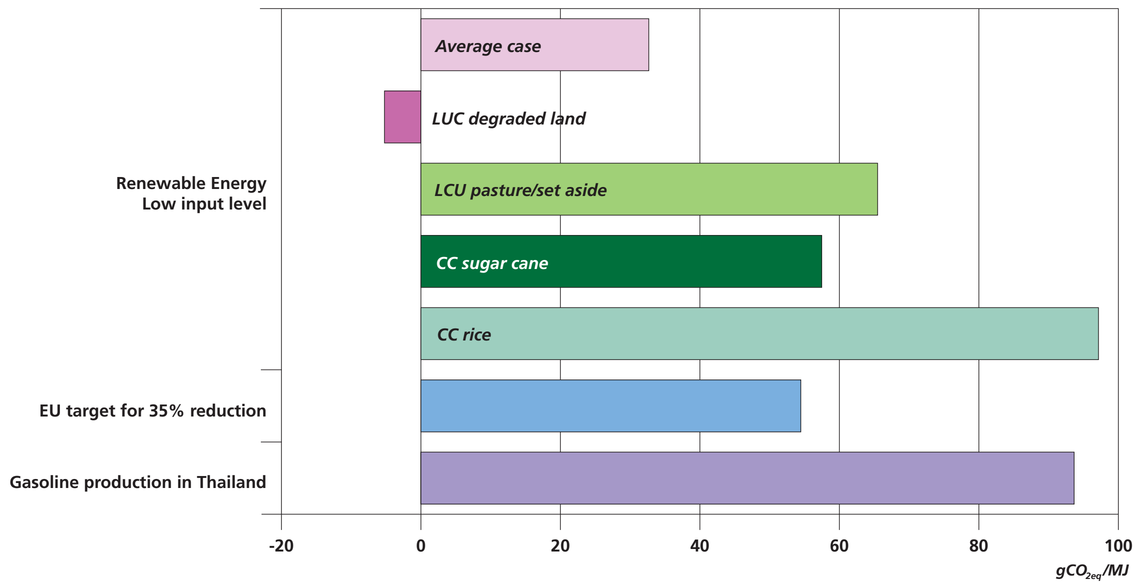
Influence of LUC and CC on the medium efficiency fossil scenario



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

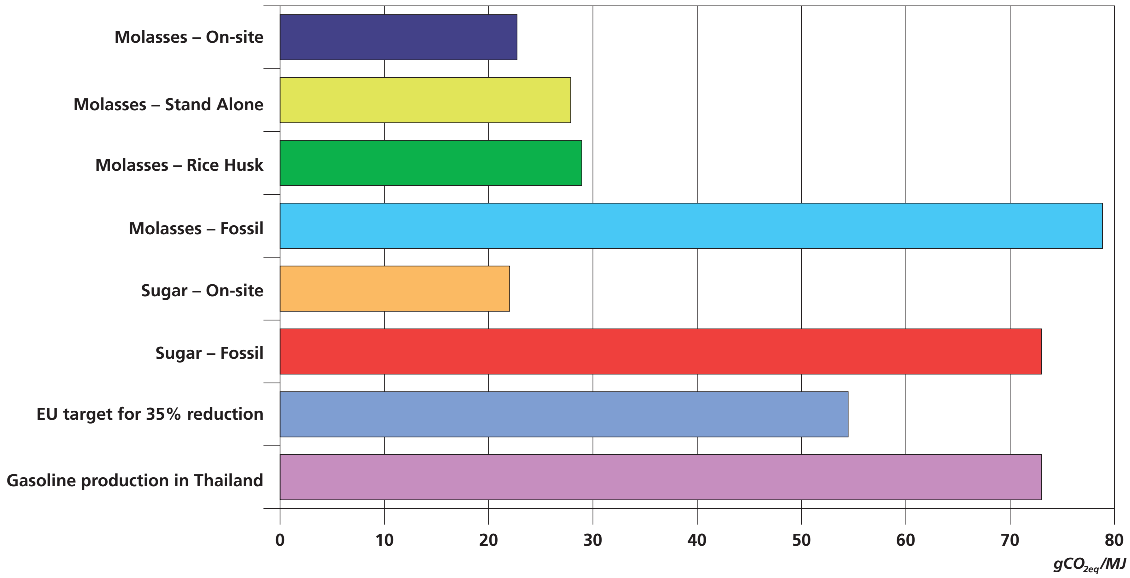
Source: JGSEE.

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

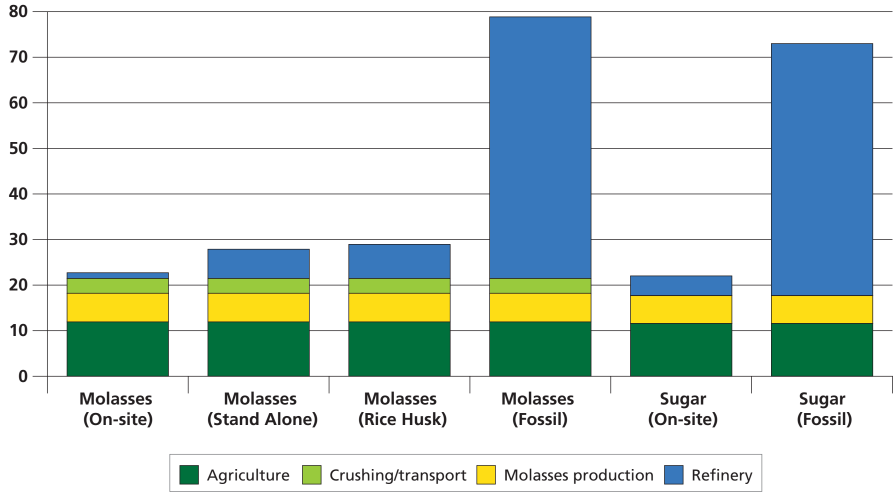


Source: JGSEE.

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.

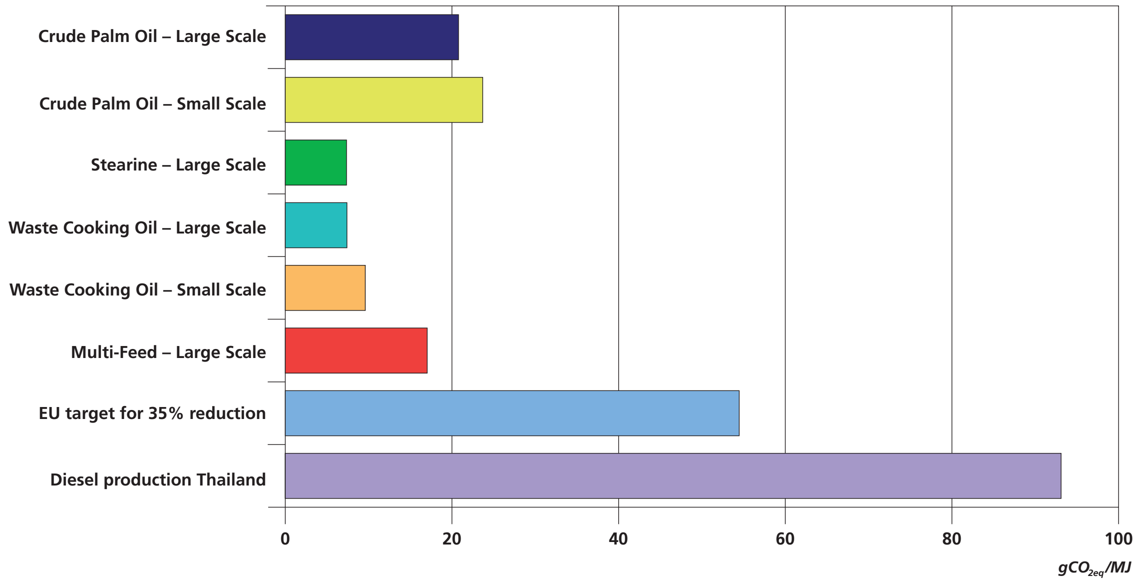
Further, in contrast to the ethanol production configurations, the largest contributor to GHG emissions in the biodiesel production is agriculture – except in the scenarios where waste cooking oil and stearine are used as feedstock. In the agriculture production step, GHG emissions are dependent upon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

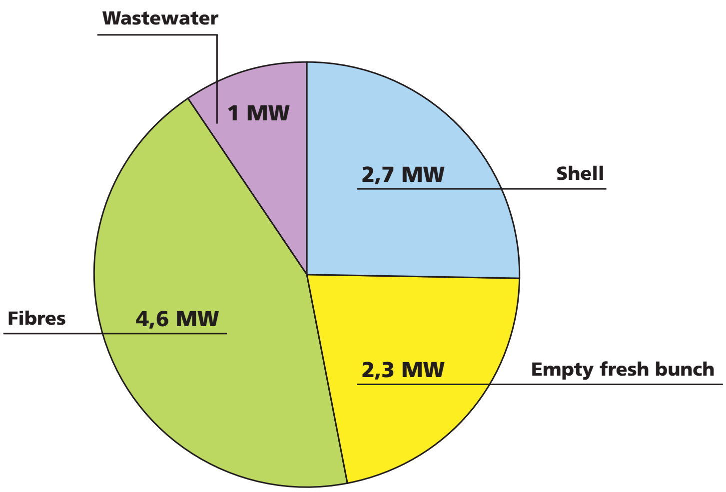
GHG emissions of different biodiesel configurations



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	No biogas use	Fossil mill
	gCO_{2eq}/MJ	gCO_{2eq}/MJ	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.

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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.

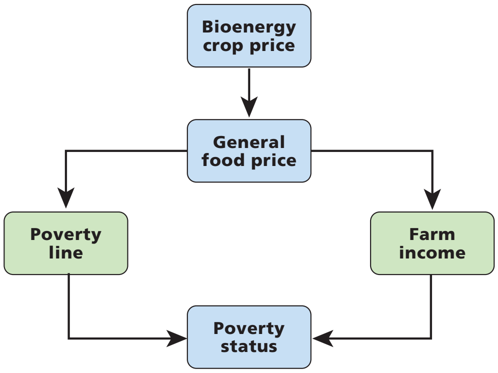
8.1.1 Microeconomic analysis

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.

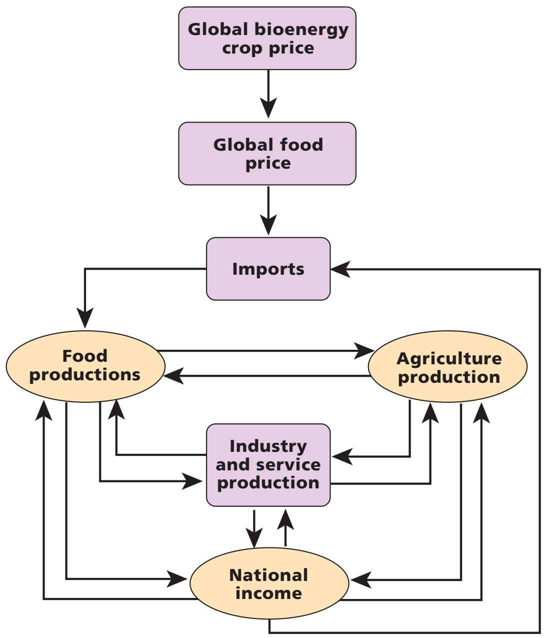
The CGE model used in this analysis was originally created by the Thailand Development Research Institute (TDRI) with financial support from the Asian Development Bank (ADB) to study the impact of organic agricultural development in Thailand (TDRI, 2009). The CGE model was constructed using 2005 data 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

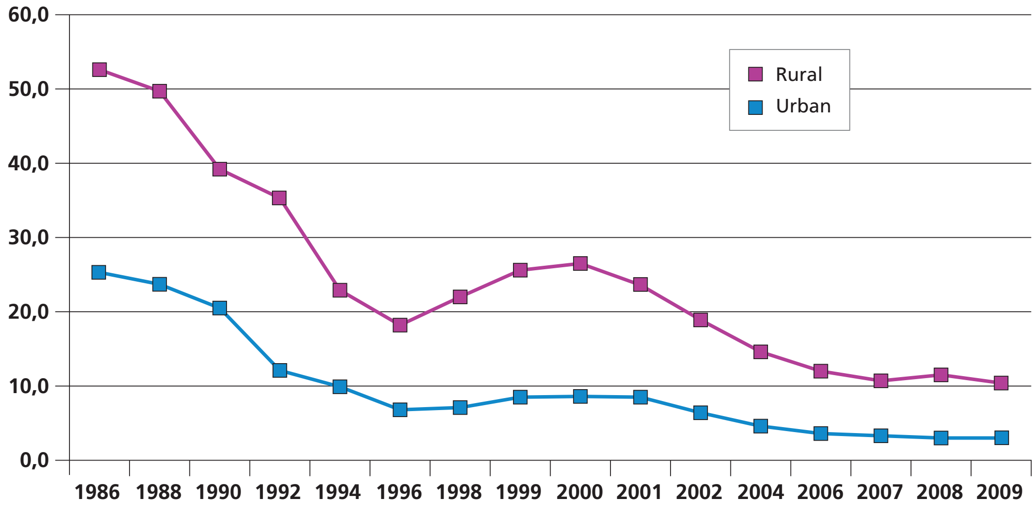
As discussed in Section 8.1.1, the impact of biofuel development on households is estimated by analysing the affect of a general rise in the price of agricultural goods; specifically food crops. For the purpose of this analysis it is assumed that changes in food prices will affect households through 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	Expenditure	Average poverty line			Poverty incidence	
			Food	Non-food	Total	Income	Consumption
	THB/person	THB /person	THB/person/ month	THB/person/ month	THB/person/ month	%	%
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

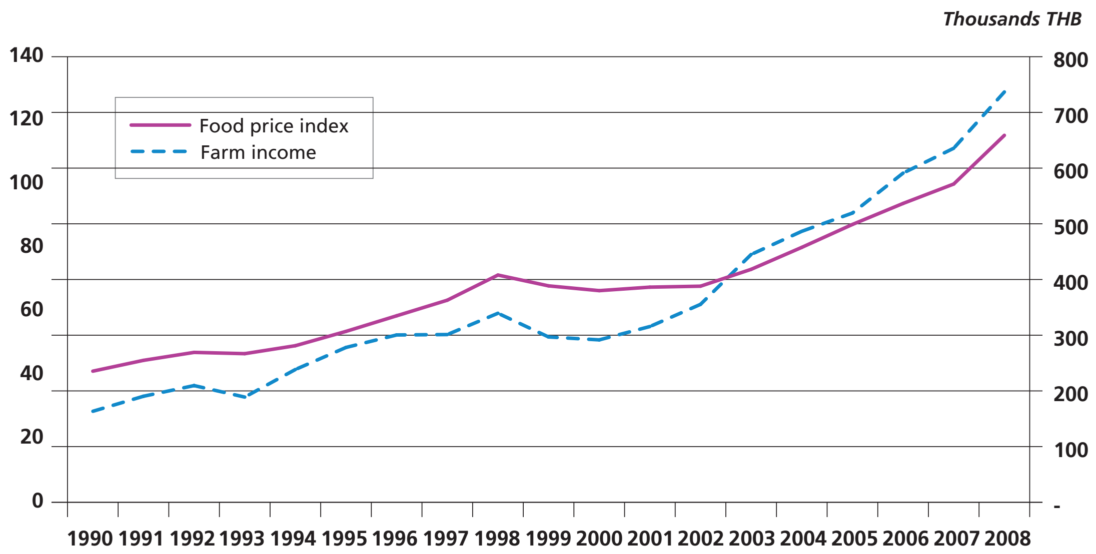
Source: NSO – calculated from 2009 Socio-Economic Survey.

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:

Farm Income = f (*food price, agricultural production*)

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

log (*Farm Income*) = 1.17 * log (*food price*) + 0.62 * (*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.

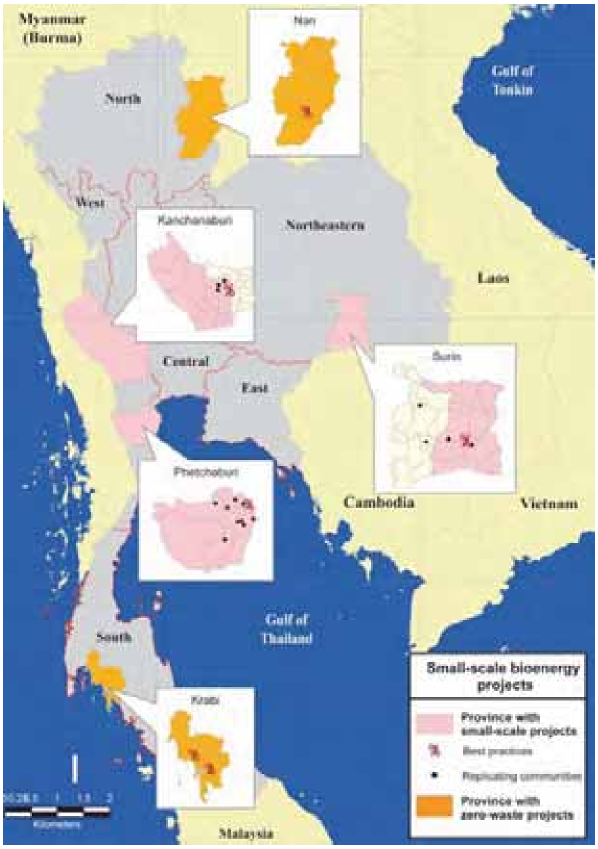
Unlike biofuels, which generally aim to provide an additional source of income for agriculture-based communities, small-scale bioenergy systems can allow rural communities to reduce energy expenditures and increase the value of otherwise discarded biomass wastes. In Thailand there is a wide-range of 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.

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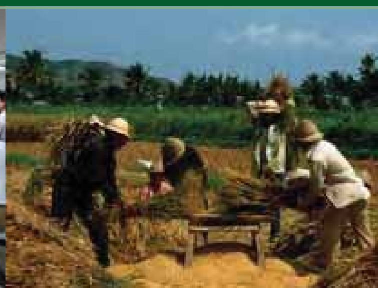
The Government of Thailand, through its Alternative Energy Development Plan, has set a target of increasing its biofuels production to five billion litres by 2022. The Thai Government sees this expansion as a way to strengthen the country's energy security, foster rural development and reduce greenhouse 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*".



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ISBN 978-92-5-106644-7 ISSN 2071-0992

I1739E/1/08.10