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BIOFUELS IN ASIA

An Analysis of Sustainability Options

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ACRONYMS

ADB	Asian Development Bank	kg	Kilogram
APEC	Asia Pacific Economic Cooperation	LCA	Life cycle assessment
ASEAN	Association of Southeast Asian Nations	MJ	Megajoules
BOD	Biological oxygen demand	MMT	Million metric tons
BtL	Biomass-to-liquid	MT	Metric ton
CDM	Clean Development Mechanism	MTBE	Methyl tertiary butyl ether
CME	Coco-methyl ester (coconut based biodiesel)	NARI	Nimbkar Agricultural Research Institute
CO₂	Carbon dioxide	NGOs	Non-governmental organization
CO_{2e}	Carbon dioxide equivalent	OECD	Organization for Economic Cooperation and Development
CPI	Consumer Price Index	PHEV	Plug-in hybrid electric vehicles
CPO	Crude palm oil	POME	Palm oil mill effluent
CPRs	Common property resources	PPO	Pure plant oil
DO	Dissolved oxygen	R&D	Research and Development
ECO-Asia	Environmental Cooperation-Asia Clean Development and Climate Program	RDD&D	Research, development, demonstration, and deployment
EFB	Empty fruit bunches (oil palm)	REDD	Reducing Emissions from Deforestation and Forest Degradation
ET	Evapotranspiration	RSB	Roundtable on Sustainable Biofuels
ETBE	Ethyl-tertiary-butyl-ether	RSPO	Roundtable on Sustainable Palm Oil
EU	European Union	RTRS	Roundtable on Responsible Soy
FAO	Food and Agricultural Organization (United Nations)	SAARC	South Asian Association for Regional Cooperation
FSC	Forest Stewardship Council	SVO	Straight vegetable oil
GHG	Greenhouse gas	US	United States
ha	Hectare	USAID	United States Agency for International Development
HEV	Hybrid electric vehicle	USDA	United States Department of Agriculture
ICE	Internal combustion engine	USG	United States Government
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics	VOC	Volatile organic chemicals
IEA	International Energy Agency	WHO	World Health Organization
IFEU	Institut für Energie- und Umweltforschung	WVO	Waste vegetable oil
IFPRI	International Food Policy Research Institute		
IPCC	Intergovernmental Panel on Climate Change		

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EXECUTIVE SUMMARY

Biofuels have been at the center of intense interest, discussion, and debate in recent years. The global biofuels boom began in 2004-2005 with the announcement by the United States (US) and the European Union (EU) of policies and incentives to support increased use of biofuels. In addition to spurring domestic production in several countries, especially the EU, the policies encouraged producers to seek out feedstocks and fuel from tropical and subtropical regions, initiating pan-global trade in biofuels. Soon thereafter, several Asian governments announced ambitious plans to promote biofuels production for both domestic consumption and export. Within a few years, biofuels had been transformed from a niche energy source to a globally traded commodity attracting billions of dollars in investments. Total biofuels production in Asia has grown more than five-fold since 2004, from just over 2 billion liters to almost 12 billion liters in 2008.

While it is clear that biofuels present a broad range of opportunities, they also entail significant environmental, social, and economic risks. Advocates maintain that biofuels can help displace fossil fuels and lower GHG emissions; support the farm sector; and revitalize rural landscapes in developed and developing countries. In contrast, opponents argue that biofuels compete with food crops for land, water, and agrichemicals; do not deliver cost-effective carbon emissions reductions; demand a disproportionate amount of subsidies and incentives; and negatively impact biodiversity.

Over the past 12 months, the intense volatility in the global commodity and oil markets has eroded the profitability of Asian biofuels producers. Concerns about the sustainability of biofuels imports to Europe from Asian countries have curbed export demand. Currently, biofuels production facilities in most Asian countries are operating at a fraction of their installed capacity. Many experts now believe that the biofuels bubble has burst. Policymakers are reconsidering the policy tools and mechanisms for supporting and promoting

the expansion of biofuels. For example, the EU is closely reviewing its biofuels mandate for 2020 and has banned imports of palm oil from tropical Asia, citing environmental concerns. In addition, the unfolding global economic crisis and the recent slump in oil prices may further dampen interest in biofuels. Investors are increasingly wary of biofuels, governments are rethinking their strategies toward biofuels, and some researchers are advocating a complete ban on biofuels production.

However, Asia may miss an important opportunity if biofuels are rejected summarily. Asia continues to face significant challenges related to energy and environmental issues. More than half a billion Asians, mostly in poor communities, lack access to modern forms of energy. Throughout Asia, there are local opportunities for development of biofuels on a more decentralized, local level. It is imperative that key Asian stakeholders in the government and private sectors, as well as non-governmental organizations (NGOs) and researchers carefully evaluate the sustainability prospects of different biofuels in Asia, assess international best practices that can help realize the full potential of biofuels, and design and implement the appropriate policies to enable their production and utilization in a sustainable manner.

It is against this backdrop of complex market trends, along with conflicting policies and beliefs on biofuels, that the United States Agency for International Development (USAID) identified the need for an objective, comprehensive, and fact-based evaluation of the viability of biofuels in Asia. This report was developed by USAID's Environmental Cooperation-Asia Clean Development and Climate Program (ECO-Asia). The report focuses on seven Asian countries: China, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam.¹ Throughout this report, these seven Asian nations are referred to as **focus countries**. They were selected because they either produce or plan to

¹ Six countries—China, India, Indonesia, the Philippines, Thailand and Vietnam—are the focus of the ECO-Asia Clean Development and Climate Program. Malaysia and Singapore are not ECO-Asia focus countries but were included in this study because of their key role in the biofuels industry in Asia.

produce significant amounts of biofuels. In some of the analyses, data from Singapore were also included because of its importance as a regional processor and trader of biofuels.

OBJECTIVES OF THIS REPORT

The purpose of this report is to provide an objective and comprehensive regional analysis summarizing the benefits and risks of biofuels development in Asia, and examining the distribution and use of biofuels through the lens of global climate change; biodiversity conservation; energy alternatives; food security; economic development; and local livelihoods. This report does not undertake a detailed evaluation of biofuels in comparison to other clean energy supply options for power generation and transport.²

The primary focus of this report is on liquid biofuels for transport applications, and to a limited extent the report also assesses applications for power generation in decentralized contexts. The report examines **first-generation** fuels derived from grains (e.g., corn, wheat, rice), starches (e.g., cassava), oil crops (e.g., oil palm, coconut, soy, and rapeseed), sugarcane, sweet sorghum, and non-food plants such as jatropha and pongamia; **second-generation** fuels (cellulosic ethanol) produced either from agricultural residue or from dedicated “energy crops” such as grasses and fast growing trees; and **third-generation** fuels, primarily focused on biodiesel produced from microalgae.

The report is intended to serve as a resource for decision-makers in the focus countries and to contribute to the ongoing national and international dialogue on biofuels development. It is not intended to offer prescriptive measures for countries, but rather to identify priority areas that may benefit from greater attention at the national, regional, and international levels. The report will also be used to inform the planning process for possible future activities funded by USAID that may address these challenges. It is hoped that the report will help inform the decision-making of other US Government agencies, multilateral development banks, and USAID partners.

KEY FINDINGS AND CONCLUSIONS

This report addresses three broad questions (see **Section I 0** for detailed conclusions):

I. Do any of the biofuels that can be produced in Asia have the potential to replace fossil fuels as a sustainable energy source and simultaneously reduce net GHG emissions?

By 2030, biofuels will meet only an estimated 3-14 percent of the total transport fuel demand in Asia. This estimate is predicated on the optimistic scenario that countries will rapidly expand cultivation of efficient first-generation biofuels crops on underutilized land while promoting second-generation, “cellulosic ethanol” using agricultural residues.

*Overall, **non-irrigated sugarcane grown on existing croplands**, with efficient use of co-products and wastes, has the most favorable net energy and GHG balance, making it one of the best crops for ethanol production in Asia, where conditions allow. For biodiesel, **oil palm** provides the best net energy and GHG benefits, but only when its cultivation does not involve land conversion and when there is full utilization of co-products and wastes. **Sweet sorghum** holds much promise as an ethanol feedstock in the near term. **Jatropha** may provide significant advantages as a biodiesel feedstock; however, a complete evaluation cannot be done in the absence of detailed information on its agronomy and fuel yield under commercial conditions. Biofuels can be an important part of national strategies to expand access to modern energy to more than half a billion people in Asia. Decentralized energy production systems, when managed by community-level institutions, can help to support rural livelihoods, ameliorate local soil and water quality problems, and reduce GHG emissions—to the extent that they avoid forest loss and displace fossil fuels.*

Large-scale production of biofuels is unlikely to make a significant contribution to Asia’s future transport energy demand. By 2030, biofuels will account for only an estimated 3-14 percent of the total transport fuel mix in the focus countries, with the greatest contribution occurring in Thailand, India, and Indonesia, assuming rapid expansion of high-yielding, first-generation biofuels crops on underutilized land, as well as the rapid commercialization and scale-up of cellulosic ethanol production from agricultural residues.

² Readers interested in such an analysis are referred to: USAID, May 2007, From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change, Bangkok, Thailand.

Countries vary in their ability to achieve national ethanol and biodiesel mandates. All the focus countries except Indonesia and the Philippines are expected to achieve their ethanol blending targets. Only Indonesia, Malaysia and the Philippines are expected to meet their biodiesel blending targets (see Section 5).

Many biofuels have limited GHG or net energy benefits. Generally speaking, only high-yielding feedstocks grown on existing cropland and converted to fuel using highly efficient processes result in significant net energy and GHG benefits. Ethanol produced from non-irrigated sugarcane grown on existing croplands or degraded land, with efficient use of co-products and wastes, has the most favorable net energy and GHG savings. Ethanol produced from sweet sorghum grown on degraded land as well as cellulosic ethanol also provide favorable energy and GHG balances. However, current grain-based biofuels systems in Asia result in negative or low net energy and GHG savings. Biodiesel produced from oil palm provides the best net energy and GHG benefits, but only when its cultivation does not involve land conversion and where there is full utilization of co-products and wastes. Biodiesel produced from jatropha planted on degraded land and coconut produced under optimal conditions can also provide benefits compared to fossil fuels.

Most large-scale biofuels production systems are not economically viable without extensive subsidies and are subject to boom and bust cycles.

Asian biofuels are expensive relative to fossil fuels, and effective utilization of co-products and wastes can be crucial to achieve profitability, which is otherwise highly volatile. In Asia, ethanol from molasses and biodiesel from oil palm and waste oil tend to have the lowest production costs.

The return on investments (both public and private) and the rate of market maturation will depend on how government policy, R&D, and operating costs evolve. In addition, opportunities for expanded trade in biofuels will be limited as long as countries enforce trade barriers and protectionist policies.

The greatest promise for biofuels in Asia lies in decentralized production and use. Decentralized energy production systems, when managed by community-

level organizations, can help to support rural livelihoods, ameliorate local soil and water quality problems, and—to the extent that they avoid deforestation and displace fossil fuels—reduce GHG emissions. The preliminary results are promising for several small-scale decentralized pilot initiatives using jatropha, pongamia, and oil palm.

2. Under what conditions should the above biofuels be produced, distributed, and consumed to avoid threats to biodiversity conservation; food security; impacts on fuel prices, smallholders, and rural livelihoods; and other economic, social, and environmental concerns?

Biofuels should be produced in a way that minimizes the use of land, water, fertilizers and fossil energy, and does not exacerbate the pollution of air, water, and soil. The focus should be on feedstocks that do not compete with food production. This can be done by establishing plantations on land that is currently not under food production. Dedicated measures that promote involvement of smallholders, fair trade, labor rights and the rights of indigenous peoples are required to ensure equitable outcomes from biofuels expansion. Smart economic subsidies and incentives are needed to strengthen best practices in existing production systems while paving the way for more efficient feedstocks and technologies. This will ensure that countries are not locked into supporting inefficient, expensive, and unsustainable options. Finally, the dismantling of trade barriers and the establishment of effective standards and certification systems can help promote a modest level of regional and international trade in sustainable biofuels.

Sustainable biofuels policies are needed to safeguard food security. Recent analyses have concluded that the demand for biofuels contributed to higher food prices during 2005-2008, although the magnitude of the influence is subject to debate. The impact of biofuels on food prices in Asia was lower than in other regions, although ethanol from corn and cassava, and biodiesel from oil palm may have contributed to higher prices for food, feed, and edible oils, respectively. While food prices have dropped recently, it is likely that competition between food and fuel will resume in time. In the medium- to long-term, strategies to ensure food security include: (1) intensifying food production and enhancing yields in existing croplands; (2) restricting biofuels crops to marginalized lands not used

for food crop production; and (3) increasing reliance on non-food-based and cellulosic ethanol feedstocks.

The environmental impacts of biofuels depend greatly on the type of feedstock, production system, location, and land cultivation practices.

The cultivation of grain-based feedstocks tends to result in higher associated environmental impacts than oil seeds, oil palm, sugarcane,³ and perennial crops. Sweet sorghum, due to its low demand for water and nutrients, has relatively low impacts, as do jatropha and second-generation feedstocks, owing to their perennial nature and low water and nutrient requirements. Growing biofuels on either croplands or marginalized lands using business-as-usual agricultural practices will exacerbate soil erosion, increase nitrate- and phosphate-related water pollution, and cause a decline in biodiversity. In India and China, large-scale biofuels production can increase demand for fresh water and exacerbate water shortages. Biofuels cultivation can avoid significant environmental impacts through the adoption of agricultural best practices at every stage of production. The conversion of “new” lands, such as primary and secondary forests, to biofuels production, presents a significant threat to biodiversity, particularly in Indonesia, where large tracts of primary rainforest may be slated for biofuels plantations.⁴

On balance, switching from fossil fuels to biofuels may benefit local air quality in Asia. Although land clearing and vegetation burning remains a significant concern, increased use of biofuels could result in reduced ambient levels of sulfur oxides (SO_x), particulates, and carbon monoxide (CO). However, in some cases, biofuels, especially biodiesel, can cause increased emissions of nitrogen oxides (NO_x) and formation of ozone (O₃).

Positive social impacts are not a guaranteed outcome from the large-scale deployment of biofuels. While ethanol production systems have a strong tendency toward economies of scale and neglect of smallholder-based production, biodiesel appears to be better suited to smaller-scale operations. There is widespread evidence across Asia that the development

of biofuels can perpetuate poor labor rights and working conditions, threaten lands used by indigenous and marginalized communities, and precipitate local conflicts over resources. Focused policy interventions to address these concerns can include support of smallholders through contract farming arrangements and technical assistance, as well as enforcement of labor rights, protection of land rights, participatory processes for indigenous peoples, and implementation of certification systems.

An international framework is needed for sustainable standards and certification of biofuels.

An international dialogue on sustainability criteria and the development of transparent and harmonized standards and certification schemes is currently under way through the Roundtable on Sustainable Palm Oil (RSPO), the Roundtable on Sustainable Biofuels (RSB), and other forums.⁵ It will be important for smallholders and other stakeholders in developing countries to receive the necessary technical assistance to be able to comply with these schemes. Also, given the projected growth in domestic demand for biofuels in Asian countries, it will be important for certification efforts to focus on both domestic and export markets.

Smart incentives are needed to promote sustainable biofuels. Experience to date strongly suggests that existing policies and incentives for biofuels production have been counterproductive and, in most cases, too expensive. Subsidies for current biofuels production systems that ignore more efficient next-generation technologies could lock-in inefficient, unsustainable practices.

Mandates and targets alone have been shown to create undesired effects because they have scaled up production very quickly. A more cautious and comprehensive approach combines mandates or targets with explicit sustainability criteria and related measures to encourage sustainable production of biofuels. These targeted measures include capital grants, low-interest or guaranteed loans, demonstration projects, technical assistance, and research and development specifically for biofuels that are produced sustainably.

3 Except in cases where large amounts of water are used to grow irrigated sugarcane (e.g. India).

4 Recently the Ministry of Agriculture in Indonesia announced that it plans to remove an existing ban on the conversion of significant amounts of peatlands—which store large amounts of carbon and support biodiversity—into plantations.

5 One such forum, the Global Bioenergy Partnership (www.globalbioenergy.org), in which the US government is a leading partner, is developing a harmonized approach to GHG emissions reductions from biofuels as well as a voluntary framework of international sustainability principles on bioenergy.

Support is needed to dismantle trade barriers and establish certification systems. Asian countries, like those in the OECD, have erected a suite of import tariffs and non-tariff barriers that restrict the use of foreign raw materials or processed biofuels. Efforts to dismantle trade barriers should be coupled with strict certification systems for quality and sustainability.

Decision-making under uncertainty. The uncertainty and potential pitfalls surrounding the environmental, social, and economic viability of biofuels makes it difficult to structure appropriate biofuels policies or make investment decisions. A two-tiered decision tree presented in this report (see **Section 9**) offers a framework for guiding decisions on individual biofuels development projects—the primary assessment addresses environmental, economic, and social issues, while the secondary assessment helps project developers improve project performance and competitiveness.

3. What priority interventions by USAID would be most useful in promoting the sustainable production of biofuels in Asia?

USAID could encourage the development of a sustainable biofuels industry in Asia through support for land resource mapping and agronomy research, promotion of second-generation and third-generation biofuels, support for development of sustainable biofuels policies, and establishment of certification systems and standards for quality and sustainability. Technical assistance areas that are best addressed within a regional context include the development of biofuels policy, replication and scale-up of decentralized biofuels projects, and development of standards and certification systems for quality and sustainability.

Develop a policy framework for sustainable biofuels in Asia. Asian governments need to review the cost-effectiveness of current biofuels policies with respect to energy security and environmental impacts, and then promote those policies that will foster long-term sustainability. For example, USAID could support a regional dialogue on policies addressing sustainable biofuels production and regional trade.

Improve land resource maps. Claims about the extensive availability of land in Asia for biofuels production

are often based on gross-scale national maps that do not reflect land quality, current land use, local populations, or conservation value. In partnership with local NGO and civil society partners, USAID and its US government partners could support detailed land resource assessments to identify the availability of marginal lands, in cooperation with national governments.

Support scale-up and regional replication of sustainable, decentralized biofuels projects.

There is an opportunity to scale up ongoing efforts that have been initiated by donors and NGOs to support community-level projects for feedstock development and energy production from biofuels. USAID could support the replication and scale-up of best practices by providing technical assistance to: (1) establish local cooperatives, marketing associations, and coordinated supply systems for larger production facilities; (2) support small-scale and carbon financing; and (3) improve small-scale processing and increased local use of vegetable oils and fuels in engines and generators.

Support agronomy research and crop improvement. The rate at which non-food crops, such as jatropha and pongamia, and cellulosic ethanol feedstocks, are commercialized will depend on how quickly Asian countries can better understand and tailor production systems to maximize yields under local growing conditions. USAID could facilitate US-to-Asia and Asia-to-Asia research partnerships and technology transfer in association with key regional entities such as the International Rice Research Institute (IRRI) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Support development of regional environmental standards and certification schemes. USAID could play an important role by supporting the development of national and regional standards and protocols within Asia that are consistent with emerging international standards, performance guidelines, and certification schemes (such as RSPO and RSB), and by providing technical assistance on compliance efforts to smaller, decentralized operators.

Support technology transfer on cellulosic ethanol. Given the advantages of cellulosic ethanol over first-generation biofuels, it will be important to facilitate

the transition to second-generation technologies in developing countries. Current research, development, demonstration, and deployment (RDD&D) efforts under way in the US could be transferred to Asia through public-private partnerships, demonstration projects, and technology transfer initiatives. USAID can also facilitate the sharing of research findings, best practices, and lessons learned among Asia's key research centers and international research bodies.

Provide technical assistance on life cycle analyses (LCAs).

LCAs have become an important tool to evaluate biofuels feedstocks and production systems. To date, only a handful of LCA studies have been carried out for Asian feedstocks and locations. USAID can support capacity building for Asian stakeholders to conduct LCAs for various Asian feedstocks and growing conditions, in order to help Asian policymakers, investors, project developers, and community organizers make informed decisions that will facilitate the scaling up of biofuels production in a sustainable manner.

SECTION I

INTRODUCTION

I.1 CONTEXT

The global biofuels boom began in 2004-2005 with the announcement of a range of incentives and support policies by the United States (US) and the European Union (EU). An expansion in the use of biofuels in the transport sector was expected to help bolster energy security, mitigate greenhouse gas (GHG) emissions (primarily carbon dioxide, or CO₂), and provide alternate markets for agricultural commodities while also stimulating the farm sector. In an attempt to source greater amounts of cheap biofuels to meet local demand, the EU began to look to producers in tropical and subtropical regions, initiating a global increase in biofuels production.

Within a couple of years, biofuels had transformed from a niche energy source dominated by small operators and a handful of countries to a globally traded commodity attracting billions of dollars of private capital from major oil producers, venture capitalists, clean energy funds, and public resources. Asian governments followed suit and announced aggressive plans to promote biofuels production and utilization. In some cases, these plans were motivated by the desire to reduce dependency on costly oil imports and to accelerate rural employment. In others, governments sought to maximize export revenue from the sale of feedstock or fuels produced from agriculture or plantation crops. In 2008, global production of biofuels was estimated to have exceeded 89 billion liters (85 percent of which was ethanol), more than triple the production level of 2000. During this same period, biodiesel production increased more than ten-fold to more than 12 billion liters.

Despite this accelerated growth, production volumes still accounted for a miniscule share of the overall transport fuel mix, comprising a mere 1 percent of total global transport fuel consumption in 2007, up from 0.4 percent in 1990. In the case of Asia, in 2008, biofuels accounted for 3 percent of the transport fuel mix. However, even at such a small scale, it is becoming evident that

biofuels—while they clearly present a broad range of opportunities—entail substantial trade-offs and significant economic and environmental risks. Opponents of biofuels argue that: they exacerbate food insecurity by competing with food crops for land, water, and agrichemicals; do not deliver cost-effective carbon emissions reductions; require a disproportionate amount of subsidies and incentives; and negatively impact biodiversity. In contrast, advocates maintain that biofuels can help displace fossil fuels and lower greenhouse gas (GHG) and other pollutant emissions, support the farm sector, and revitalize rural landscapes in developed and developing countries.

Against the background of this often highly polarized debate, most stakeholders now believe the biofuels bubble has burst. Stock prices of leading US ethanol producers had collapsed well in advance of the recent economic crisis. The EU is closely reviewing its biofuels mandate for 2020 and has stopped importing oil palm from tropical Asia, citing environmental concerns. This has led in the short term to a catastrophic decline in production in Malaysia and Indonesia and idling of installed capacities. Meanwhile, India has also announced a review of its biodiesel expansion plans. The present unfolding global economic crisis and recent slump in oil prices and demand may further dampen interest in biofuels. The end result is that the pendulum appears to have swung to the other extreme. Investors are wary of biofuels, governments are rethinking their strategies, and most civil society actors and some academic researchers advocate a complete ban on biofuels.

The receding over-enthusiasm presents an opportunity to take a careful and fact-based approach to examining the viability of biofuels. This report concludes that it is neither practical nor desirable to completely ban the development and use of biofuels. While expansion entails substantial economic and ecological risks, a rush to entirely reject biofuels forgoes significant opportunities to use biofuels sustainably, improve land use and agriculture, and to develop fossil fuel alternatives.

It is important to understand the Asian context in evaluating the role and future of biofuels. Asia continues to face persistent, broad challenges related to energy and environmental issues. More than half a billion Asians do not have access to modern forms of energy. A large increase in petroleum use in recent years has led to a deterioration of local air quality and increased levels of GHG emissions, while rendering these countries increasingly dependent on imported oil. Further, governments in Asia continually face challenges to increasing agricultural productivity and stimulating rural employment.

The rapid expansion of biofuels in many countries poses significant challenges for policymaking. The issues surrounding the expansion of biofuels production and utilization are complex and highly dependent on the type of crop, local circumstances, and production management systems. Biofuels do not lend themselves to easy generalizations. Most of the impacts are long-term and carry a high degree of uncertainty. As policymakers develop and implement national biofuels expansion plans, they will need to contend with an environment of uncertainty, polarized positions, and an ambiguous economic future. Their priority should be to identify and promote approaches to biofuels production and utilization that enhance energy access to the poor; reduce dependency on oil imports, and diversify markets and livelihoods in rural areas, and to reduce GHG emissions, while excluding approaches that undermine food security, degrade natural resources, and impoverish their citizens.

1.2 OBJECTIVES OF THIS REPORT

The purpose of this report is to provide an objective, up-to-date, and comprehensive regional analysis summarizing the overall near- and long-term advantages and disadvantages of biofuels development with respect to: addressing global climate change; promoting biodiversity conservation; ensuring food security; supporting economic development; and supporting local livelihoods.

Funded by USAID as part of its ECO-Asia Clean Development and Climate Program, this report analyzes the current status and prospects for biofuels development

in Asia, and highlights the inherent risks and opportunities associated with their widespread production and use. It focuses on liquid biofuels for transport, and includes some discussion of biofuels for power generation in decentralized contexts. However, the report does not undertake a detailed evaluation of biofuels in comparison to other clean energy supply options for power generation and transport.¹

The report be used to inform the planning process for possible activities funded by the U.S. Agency for International Development (USAID), and it is hoped that it will help inform the decision-making of other US agencies, multilateral development banks, and other USAID development partners. The goal of the report is to serve as a resource for decision-makers and to contribute to the international debate surrounding biofuels development. It is not designed to provide prescriptive measures, but rather to identify key issues and areas that deserve priority attention at the national, regional, and international levels.

1.3 APPROACH AND METHODS

The report focuses on seven Asian countries: China, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam.² These countries either produce or plan to produce significant amounts of biofuels in the future. Singapore was also included in some analyses because of its importance as a regional processor and trader of biofuels. These countries are referred to as focus countries. The report seeks the answers to three primary questions:

- Do any of the biofuels produced and used in Asia have the potential to replace fossil fuels as a sustainable energy source and simultaneously reduce net GHG emissions?
- Under what conditions should the above biofuels be produced, distributed, and consumed in a manner that avoids threats to biodiversity conservation; does not threaten food security; minimizes impacts on fuel prices, smallholders, and rural livelihoods; and addresses other economic, social, and environmental concerns?
- Which priority interventions by USAID would be most useful in promoting sustainable production and markets for biofuels in Asia?

¹ Readers interested in such an analysis are referred to: USAID, May 2007, *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, Bangkok, Thailand.

² Six countries—China, India, Indonesia, the Philippines, Thailand and Vietnam—are the focus of the ECO-Asia CDCP. Malaysia and Singapore are not CDCP focus countries but were included in this study because of their key role in the biofuels industry in Asia.

In order to address these questions, this report:

- provides forecasts of petroleum fuel supply and demand trends;
- synthesizes information on current biofuels production, trade, and expansion plans;
- estimates potential production and ability to meet national biofuels mandates;
- evaluates current impacts of biofuels production on social, economic, and environmental indicators, and highlights emerging best practices;
- compares the sustainability potential of various biofuels feedstocks;
- identifies country-level risks and opportunities; and
- develops policy guidelines for consideration by national, regional, and international actors in Asia, specifically including a set of advisory needs for technical assistance support by USAID.

Methods. The report was prepared through stakeholder consultations in the focus countries, and an analysis of data trends, key reports, and analyses relating to biofuels. From October through December 2008, the ECO-Asia research team consulted with key biofuels stakeholders (i.e., public agencies, research institutes, private sector actors, and trade associations) in the focus countries. In parallel, researchers in each country collected and analyzed data on their domestic biofuels sector. Sector specialists developed background papers and analysis for specific sections. Overall, this report is based on meeting notes from the in-country consultations and interviews; desk reviews of key data sources, reports, and analyses produced by the United Nations (UN) Food and Agriculture Organization (FAO), World Bank, Asian Development Bank (ADB), the Organization for Economic Cooperation and Development (OECD), and others; and email, phone, and in-person interviews with subject matter experts and regional institutions that specialize in aspects of biofuels development and utilization.

The report provides a comprehensive overview of relevant technological, economic, social, and environmental issues, but it is by no means an in-depth analysis. Its intent is to provide an overview, highlight key conclusions or findings,

and draw out implications for policymaking and program planning. Readers interested in more in-depth information should refer to the many excellent reports and journal articles produced on various biofuels topics in recent years by major international development agencies, donors, research institutions, and university researchers. The authors have relied extensively on these references and have cited them throughout the report.

I.4 STRUCTURE OF THE REPORT

Following this introduction, **Section 2** analyzes projected demand for petroleum fuels in Asia during the period 2008-2030, and related impacts on the environment and on national budgets and households. **Section 3** is a primer on biofuels and provides a description of various feedstocks and conversion technologies. **Section 4** provides an overview of the production and trade of biofuels, with a special focus on Asia and the current state-of-play with respect to commercial actors in the biofuels marketplace. **Section 5** estimates potential production that could be achieved from wasted grain/crop, greater penetration of new biofuels crops and advanced conversion technologies, and use of underutilized lands. As part of the analysis, the production potential is compared to the existing/proposed mandates or targets for biofuels in the various countries to determine whether they can be met.

Section 6 explores the sustainability of large-scale deployment of biofuels, addressing a range of environmental, economic, social, and technological issues. **Section 7** describes policy guidelines and illustrative support mechanisms that are required to ensure that biofuels development is sustainable. **Section 8** evaluates various biofuels feedstocks based on a set of sustainability criteria. **Section 9** summarizes and analyses stakeholder inputs and key issues for the focus countries. **Section 10** describes a decision support framework for managing uncertainty related to the development of biofuels. Finally, **Section 11** provides a summary discussion and identifies a set of priority areas for USAID to consider for future technical assistance programs in the Asia region.

SECTION 2

FUTURE DEMAND FOR PETROLEUM FUELS IN ASIA

This section estimates the expected impacts from continuing the status quo with traditional transport fuels in Asia. Six scenarios are presented for demand growth of gasoline and diesel fuel, followed by a discussion of impacts on local air quality and GHG emissions, government expenditures, foreign exchange reserves, and personal transportation costs.

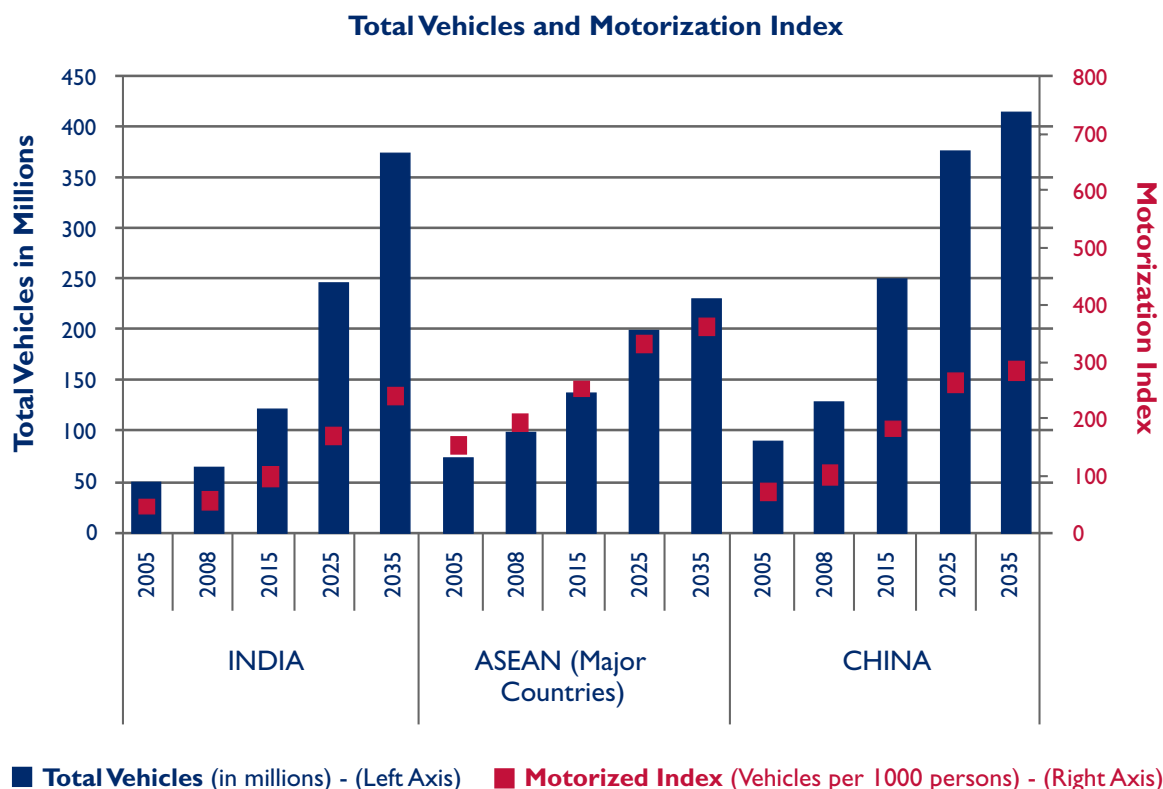
Gasoline and diesel fuel demand in Asia is projected to increase 15-350 percent by 2030, along with a concomitant increase in related GHG emissions. Fossil fuels used in transport currently contribute 5-48 percent of total particulate matter in Asian cities. The need to import greater amounts of fossil fuels to meet increased demand for transport fuel is expected to place additional strains

on national budgets. If future demand for transport fuel follows the high growth scenario detailed in this section, governments will need to increase their present subsidies by more than three-fold to maintain current domestic fuel prices.

2.1 GROWTH IN DEMAND FOR GASOLINE AND DIESEL

The number of vehicles has increased rapidly over the last decade in Asia in tandem with regional economic growth (**Figure I**). Through 2035, under a business-as-usual scenario, total vehicles will double in major Association of Southeast Asian Nations (ASEAN) nations, triple in China, and grow five-fold in India.

FIGURE I. Growth in Number of Vehicles and Motorization Index in Asian Countries



Source: Fabian, 2008

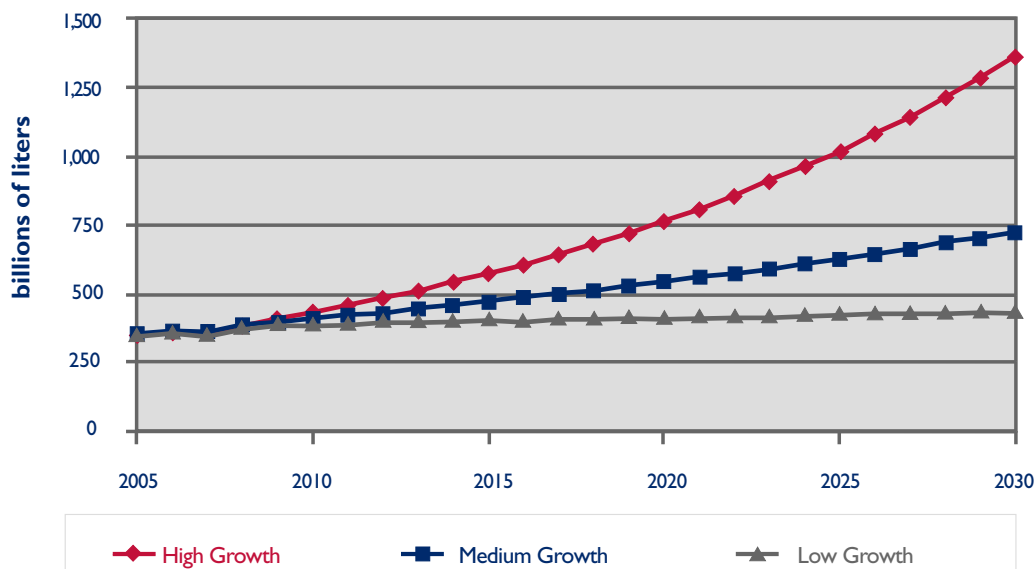
Projections suggest that by 2030, overall transport fuel demand in the focus countries could increase by 15 percent to 350 percent depending on the scenario (**Figure 2** and **Table I**). The low-growth scenario assumes that demand for gasoline and diesel will increase at the rate of population growth, estimated to range from 0.6 percent (China and Vietnam) to 2 percent in the Philippines (US Bureau of the Census, 2008). The medium-growth scenario is similar to the International Energy Agency's (IEA) and US Energy Information Administration's (USEIA) reference case, which projects annual demand growth at 3-4 percent for non-OECD Asia, assuming global recovery from the ongoing recession by late 2009 (USEIA, 2008a; IEA, 2008b). In the high-growth scenario, demand increases by approximately double the medium-growth rate or 6-7 percent annually. Scenarios use demand in 2008 as the baseline and escalate using the growth rates assumed under each scenario.¹

2.2 EFFECTS ON LOCAL AIR POLLUTANTS AND GREENHOUSE GAS EMISSIONS

Emissions of air pollutants such as nitrogen oxides (NO_x), sulfur oxides (SO₂), hydrocarbons, and particulate matter (PM) are determined by the chemistry of the fuels and the age and maintenance of the engines in which they are combusted. Gasoline and diesel are associated with higher emissions of pollutants than compressed natural gas. The share of particulate matter, for example, in megacities in Asia attributed to transportation, based on series of source apportionment studies,² is estimated to be between 5 and 48 percent of the total pollutant loads (**Figure 3**).

Assuming that current fuel composition and engine standards will persist into the future, the emission levels of

FIGURE 2. Projected Demand for Gasoline and Diesel in Focus Countries (2008-2030)



Source: USAID ECO-Asia Clean Development and Climate Program, 2009; Country level ministries and bureaus of statistics

¹ Although there is growing evidence to suggest that global supplies may struggle to keep up with demand and may in fact decline in the next 20 years (Hallock et al., 2004; USGAO, 2007), for simplicity, the scenarios assume an increase in global supply of petroleum through 2030 to meet growing demand. The projections also do not assume changes in demand dynamics between fuels. In most focus countries, diesel demand is higher than gasoline demand, though some projections, such as those of the IEA, predict that with relative changes in the kind of vehicles within the country, overall demand dynamics may shift toward gasoline.

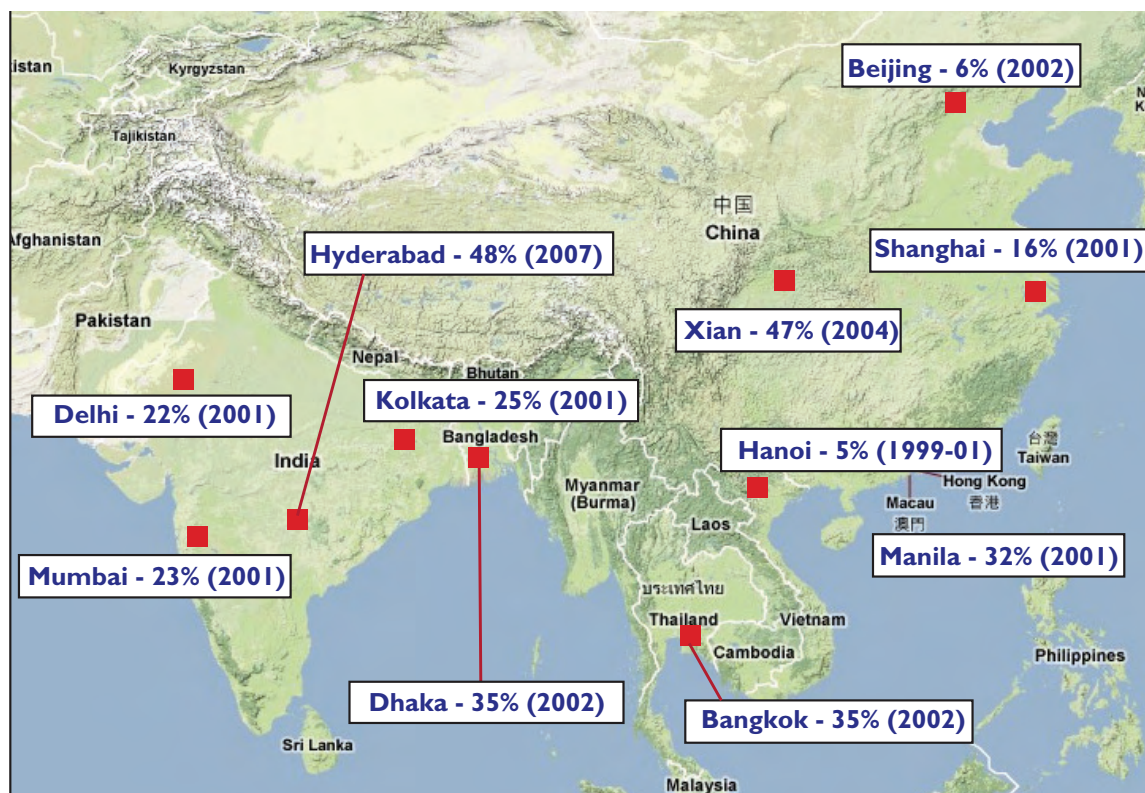
² Data from ambient monitoring of PM was linked back to emission sources and pollutants through chemical and bio-marker analysis (includes statistical regression analysis for source profiles). This allows for conclusions to be derived that a certain portion of the PM sample at the measured hot spot arrived from transport sector. The estimates represent direct vehicular emissions and do not include fugitive dust from paved and unpaved roads due to the vehicular activity, which constitutes a major part of the measured particulates, especially in the developing countries. It is important to note that the results presented in the Figure are based on monitoring data (operated at limited capacity), and in reality, the exposure levels and period of transport related pollution is expected to be higher.

TABLE I. Forecasts of Annual Gasoline and Diesel Consumption in the Focus Countries (billions of liters)

COUNTRY	2008			2030								
	Actual			Low Growth Scenario			Medium Growth Scenario			High Growth Scenario		
	Petrol	Diesel	Total	Petrol	Diesel	Total	Petrol	Diesel	Total	Petrol	Diesel	Total
China	79.3	157.9	237.2	87.8	174.8	262.6	152.0	302.6	454.5	285.8	569.0	854.8
India	11.2	47.5	58.7	13.0	55.1	68.1	23.9	101.2	125.1	49.8	210.3	260.1
Indonesia	17.6	11.1	28.7	21.9	13.9	35.8	27.3	17.2	44.5	41.8	26.4	68.2
Malaysia	9.4	6.2	15.7	13.3	8.7	22.1	14.6	9.6	24.2	22.4	14.7	37.1
Philippines	4.3	5.8	10.1	6.2	8.4	14.7	8.2	11.1	19.3	15.4	20.9	36.2
Singapore	0.3	3.5	3.8	0.4	4.0	4.4	0.4	4.3	4.7	0.6	6.7	7.3
Thailand	4.7	16.7	21.4	5.2	18.3	23.5	5.9	20.7	26.7	9.1	31.9	41.0
Vietnam	4.4	7.6	12.0	5.2	9.1	14.2	9.3	16.3	25.6	19.3	33.8	53.2
Total	131.3	256.3	387.6	153.1	292.3	445.4	241.6	483.1	724.6	444.2	913.8	1,358.0

Source: USAID ECO-Asia Clean Development and Climate Program, 2009

FIGURE 3. Percent Contribution of Transportation to Total Particulate Matter in Asian Cities



Source: Guttikunda, 2008

Note: Date is the year of the study.

local air pollutants in the future will increase in proportion to future fuel use. However, initiatives are planned to use cleaner-burning fuels and alter land-use and transportation modes in many Asian cities (Fabian, 2008). These measures can be expected to decrease emissions, although increasing levels of overall fuel consumption, and therefore overall emissions, would reverse these improvements to some extent.

Based on the scenarios for growth demand (**Figure 2**), GHG emissions in the focus countries are expected to increase between 2008 and 2030 by 15 percent under low growth, 112 percent under medium growth, and 350 percent under high growth. If aggressive fuel efficiency and mass transportation programs were implemented, they could significantly reduce emissions of pollutants in these Asian cities over the coming years.

2.3 EFFECTS ON FOREIGN EXCHANGE AND BUDGETS

Petroleum consumption also affects individual and national budgets, and the balance of trade for each country. The cost of diesel and gasoline to individuals in the focus countries depends greatly on the global

oil price and level of government subsidy. Increases in consumer fuel prices affect individual households, and such increases can provoke civil unrest, even leading to riots (Howard, 2005). The proportion of household budgets taken up by fuel depends on the cost of gasoline or diesel relative to wages. Future impacts on household budgets would depend on government policies, the price of oil, and increase in wages due to economic growth.

A nation's foreign exchange balance and government outlays are not substantially affected if domestic oil production offsets demand increases. However, production in the focus countries is currently declining or not increasing enough to offset demand (EIA, 2008b). Government subsidies increase proportionally with price and demand, and can have a major impact on nations' balance sheets and debt levels. Several of the focus countries in recent years have either reduced subsidies or proposed to reduce them. At the same time, the degree of implementation and impact of these subsidies remains uncertain (US EIA, 2006, 2007a; Richardson, 2004). Assuming petroleum prices remain constant (based on late 2007 prices) and demand follows the high-growth scenario to 2030, the cost of subsidies to maintain the same domestic price will need to more than triple.

SECTION 3

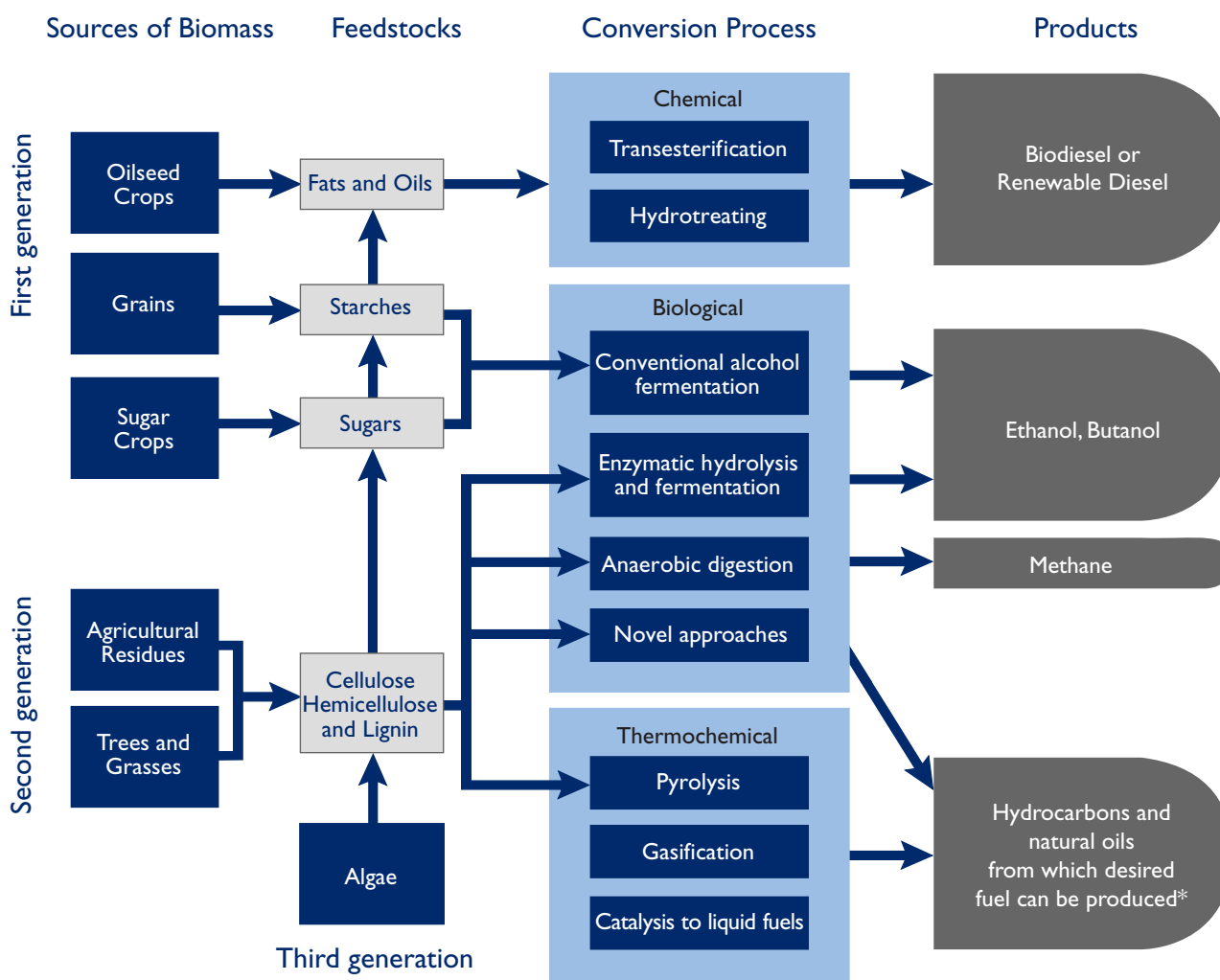
BIOFUELS FUNDAMENTALS

3.1 BIOFUELS PRODUCTION PATHWAYS

Biofuels can be derived from any biological carbon source, but photosynthetic plants are the most commonly used feedstock. Biofuels are categorized into first-generation biofuels and advanced biofuels (second-generation, third-generation, etc.). This chapter explains

current and emerging production pathways and the technical fundamentals of these categories. As **Figure 4** shows, a variety of biomass feedstocks can be transformed into biofuels via different production pathways to produce biodiesel, ethanol, butanol, methane, or other fuels; all are the subject of ongoing research. Technologies to produce first-generation fuels are mature but some feedstocks are higher yielding than others: sugarcane, sugar beet, coconut,

FIGURE 4. Technology Pathways to Transform Biomass into Biofuels



Source: Pena and Sheehan, 2007 in Pena, 2008

and oil palm are the highest yielding feedstocks. Wheat and soybean are generally the lowest-yielding. Second and third generation feedstocks are higher-yielding than most first-generation feedstocks but conversion technologies are still prohibitively expensive and commercially unproven.

3.2 FIRST-GENERATION BIOFUELS

The term first-generation biofuels generally refers to fuels produced from agricultural crops grown for food and feed, and from new oilseed crops such as jatropha and pongamia. The technologies to produce these fuels are well developed and widely used, but with the possible exception of ethanol from sugarcane, are not particularly energy-efficient, and, as discussed in Section 6, may have negative effects on food markets and the environment (Runge and Senauer, 2007; Searchinger et al., 2008). Currently, the most common forms of first-generation biofuels are ethanol (an alcohol) derived from grains or sugarcane, and biodiesel (an ester) derived from oils or fats, as shown in **Figure 4**.

ALCOHOL FUELS

The dominant, almost exclusive form of alcohol fuel currently produced is ethanol. Other forms, such as ethyl-tertiary-butyl-ether (ETBE) are blended with gasoline but in much smaller volumes. Interest in alcohols with longer carbon-chain structures, such as butanol, has increased over the last few years but production is not yet economically competitive.

Ethanol is primarily produced through the anaerobic fermentation of sugars, such as sucrose, fructose, and glucose, in the presence of yeast (**Figure 4**). These sugars can be extracted from crops such as sugarcane, sugar beets, and sweet sorghum, and can be directly converted to ethanol through fermentation. Sugars can also be extracted from starchy crops, such as feed grains, food grains (e.g., corn and wheat), and tubers (e.g., potatoes and cassava), but this requires the additional step of hydrolysis to convert the starch into sugar by means of a high-temperature enzymatic process before fermentation into ethanol. This extra step adds to the production cost and energy required.

Box 1. Sweet Sorghum: Miracle Crop?

Sorghum is a tropical cereal grass native to Africa. A hardy and drought-resistant crop, sorghum is the fifth most common crop in the world, cultivated on some 42 million hectares worldwide. Sweet sorghum, a specific variety of sorghum, has shown promise as an ethanol feedstock and compares favorably with sugarcane. Its cane-like stalks can be crushed to produce juice with higher sugar content (15-23 percent) than sugarcane (15 percent). The silage can be used as fodder or biomass fuel. It can be grown without irrigation on semi-arid lands unsuitable for many other crops. It also requires much less water than sugarcane—as little as one-fourth, according to some estimates.

India's Nimbkar Agricultural Research Institute (NARI) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) are researching the crop as a biofuel. In a single two-season growing year, an experimental hybrid grown by NARI planted on one hectare yielded 2-4 tons of grain, 15-20 tons of dry bagasse, or 3,000-4,000 liters of ethanol (Nimbkar and Rajvanshi, 2003). The latter is close to India's current ethanol yield from sugarcane. Other cultivars have reported a wider range of yields, from 2,365 to 6,366 liters per hectare (Bennett et al, 2009). ICRISAT's experiments in Andhra Pradesh and in the Philippines achieved shorter cropping seasons and lower production costs than sugarcane, with high yields of stalk (ICRISAT website).

Sweet sorghum has yet to be cultivated on a large commercial scale for ethanol production, so there are only limited data on the relationship between crop yields, soil quality, and water requirements. Sweet sorghum may prove to be an ideal feedstock. It is not in high demand in the global food market and, therefore, has a limited impact on food prices. Like sugarcane, it is expected to significantly reduce greenhouse gas emissions, though this has yet to be investigated fully.

Table 2. Average Ethanol Yields from Various First-generation Feedstocks

FEEDSTOCK	Fuel yield (Liters ethanol/ton feedstock)	Fuel yield (Liters ethanol/hectare)
Sugar beet	110	5,060
Sugarcane	70	4,550
Sweet Sorghum	40	2,800
Cassava	180	2,070
Corn	400	1,960
Rice	430	1,806
Wheat	340	952

Source: FAO, 2008; ICRISAT, 2004

Table 3. Planted Area, Yield, and Production for Selected Ethanol Feedstocks in Asia

CROP	COUNTRY	Area	Yield	Total Production
		Million hectares	Metric tons/hectare	Million metric tons
Sugarcane	India	4.27	66.2	282.67
Sugarcane	China	1.33	69.7	92.70
Sugarcane	Thailand	1.02	57	58.14
Sugarcane	Brazil	6.71	76.6	513.99
Cassava	Thailand	1.09	19.3	21.04
Cassava	Indonesia	1.62	14.5	23.49
Cassava	Vietnam	0.39	14.7	5.73
Cassava	India	0.13	8.8	1.14
Wheat	China	22.9	4.1	93.89
Wheat	India	26.2	2.7	70.74
Corn	China	25.2	5	126.00
Corn	Vietnam	0.94	3.6	3.38
Corn	Thailand	1.05	3.9	4.10

Source: FAOSTAT, 2009

Note: Values represent the average of data from 2005-2008; in most countries only a fraction of the total crop production is used for ethanol production.

Fermentation produces ethanol containing a substantial amount of water. Distillation is needed to remove the majority of water, yielding about 95 percent pure ethanol, 5 percent water. This mixture is called hydrous ethanol. When all water is removed it is known as anhydrous and it is suitable for blending into gasoline. The ethanol is usually “denatured,” often by the addition of a small amount of gasoline, which makes it unfit for human consumption. Ethanol contains approximately 66 percent of the energy provided by an equivalent amount of gasoline, but has a higher octane level. When mixed with gasoline, it improves performance and fuel combustion, lowering some air pollutants. In response to health and safety claims regarding a common oxygenate, methyl tertiary butyl ether (MTBE), many countries have mandated the use of ethanol to replace MTBE. Ethanol can be blended with gasoline up to 15 percent, but higher blends and pure ethanol require engine modification because ethanol is highly corrosive.

Sugarcane is the most production-efficient feedstock among first-generation alcohols. It is a perennial grass that grows in warm temperate to tropical climates and can be harvested four or five times before reseeding. India, China, and Thailand are among the top producers (FAOSTAT, 2008). Mills convert sugarcane into raw sugar, which is processed at a refinery into refined sugar, leaving cane molasses and bagasse. Sugar, either raw, refined, or from molasses, is directly fermented to produce alcohol. Modern plants co-fire the bagasse to generate electricity for the plant and for sale to the electricity grid.

Overall biofuels feedstock productivity is best represented by liters of ethanol per hectare produced, which is the product of the liters of ethanol per ton of feedstock and the total tons of feedstock produced per hectare. The most productive feedstocks on a per-hectare basis are sugar beet and sugarcane, followed by sweet sorghum (See **Box 1**). Corn, rice, and wheat are less productive. The theoretical yield of ethanol from one ton of sucrose is 617 liters; currently this amount is typically reduced to about 530 liters after production losses. In Brazil, where production efficiencies are among the world’s highest, sugarcane yields an average of 73.5 ton per hectare, and 75 liters of ethanol are produced from one ton of sugarcane (FAO, 2008). This results in more than 5,500 liters of ethanol per hectare.

Table 2 shows ethanol yields per ton and per hectare for various feedstocks. While sugar beet is shown to produce

more liters per hectare in this data, the numbers are global averages, and yields can vary considerably.

Table 3 shows variation in yields and total production by country and crop. For example, sugarcane yields vary substantially by country, and wheat yields in India are two-thirds of the yields in China. Yields have also improved over time. For instance, in the US average corn yields are about 9.4 metric tons per hectare, up from about 6.3 metric tons per hectare in the early 1980s.

ESTER FUELS

Biodiesel is a fatty acid methyl ester that is produced by the transesterification of fats or oils. Transesterification removes water and contaminants from the oil and breaks apart triglycerides by mixing it with an alcohol (usually methanol) and a catalyst. This process produces esters (biodiesel) and glycerin. Feedstocks include oil seeds from annual crops (e.g., soybeans and rapeseed), perennial crops (e.g., oil palm, coconut, and jatropha), waste cooking oil, and fish and animal fats. Jatropha and pongamia are two first-generation, non-food feedstocks that are attracting a great deal of interest (See **Box 2**). They have been mostly deployed on a small scale. Very little information is available on their performance in large-scale plantations.

Biodiesel has about 90 percent of the energy content of conventional diesel, but the fuel economies of both are comparable. Biodiesel’s higher oxygen content aids in achieving complete fuel combustion, thereby reducing emissions of particulate air pollutants, carbon monoxide, and hydrocarbons. It is generally used in a 5 percent blend in conventional diesel (B5), though it can be used in blends of up to 20 percent (B20) in standard diesel engines and as pure biodiesel (B100) in modified engines.

On a liters-per-hectare basis, oil palm is on average one of the highest yielding feedstocks, followed by coconut (**Table 4**). Jatropha and rapeseed have moderate yields, and soybean and sunflower have relatively low yields.

Because yields depend on local growing conditions and practices (see **Table 5**), some countries have higher productivities for certain biodiesel crops than others. This influences the types of feedstocks best suited to a particular country. For instance, China is not well-suited to growing palms. Similarly, Malaysia has achieved slightly

Box 2. Jatropha: Can it be Scaled Up?

As an energy crop, jatropha has made headlines. A perennial shrub native to Central America, it is drought-tolerant, grows well on marginalized land, and needs only moderate rainfall (between 300 and 1,000 mm per year). It is easy to establish, can help reclaim eroded land, and grows quickly. These characteristics appeal to many developing countries concerned about diminishing tree cover and soil fertility, especially those looking for an energy crop that will not compete with food crops. After as little as two years, jatropha produces seeds that contain 30-40 percent oil by kernel weight.

Jatropha's positive attributes have led to numerous projects for large-scale oil and/or biodiesel production, as well as small-scale rural development. Governments and international investors are cultivating it in Asia and Africa. The largest venture is part of India's proposed policy to replace 20 percent of diesel demand with biodiesel from jatropha. Plans call for jatropha to be cultivated on 10 million hectares of wasteland, generating year-round employment for 5 million people, although reportedly, only a fraction of the pilot-phase of 400,000 hectares is currently under cultivation (Gonsalves, 2006; Francis et al., 2005; John, 2008). Despite considerable investment, reliable scientific data are not available on the agronomy of jatropha. The evidence available shows a wide range of yields (anywhere from 464 to 2,470 liters per hectare), and it is difficult to correlate these yields with relevant parameters such as soil fertility and water use (Foidl, et al, 1996; de Fraiture et al, 2008; Prueksakorn and Gheewala, 2008). The exact nature of these inputs has not been determined for much of the land envisioned for jatropha production.

At a small scale on marginalized lands jatropha cultivation can help with soil and water conservation, reclamation, and erosion control, and can be used for fences, firewood, green manure, lighting fuel, soap, insecticides, and medicine. Therefore, jatropha on a small, localized level may be suitable because the economic drive to achieve the highest possible yields is less of a factor, although it is still important to conduct and disseminate research on crop agronomy to optimize growing conditions on marginalized lands. On the other hand, the viability of jatropha planted on marginalized land at a commercial scale is questionable because marginalized land is often remote, with little infrastructure, and experience indicates that because yields are lower under conditions of low soil fertility and water, jatropha may not be economic on marginalized lands (Jongschaap et al., 2007). The rush to develop jatropha on the basis of unrealistic expectations may not only lead to financial losses, but also may undermine confidence among local communities. If jatropha is to become a practical biofuels feedstock, more research is needed on suitable germplasm and yields under various conditions and scales, and markets need to be established to promote sustainable development of the crop.

higher productivity in oil palm compared to Indonesia, even though Indonesia has a much larger planted area.

3.3 SECOND-GENERATION BIOFUELS

Biofuels from non-food sources, specifically grown as energy crops, are commonly referred to as second-generation (also referred to as cellulosic) biofuels. Cellulosic technologies utilize the vast amount of woody biomass available, including agricultural and forest waste and residues, and municipal solid waste. The promise of harvesting these feedstocks for fuels

is attractive since current production pathways cannot utilize the majority of plant material, which includes cellulose, hemi-cellulose, and lignin. Lignocellulose can also be obtained from planted trees and shrubs (e.g., willow, eucalyptus) and dedicated short-rotation grasses (e.g., switch grass and miscanthus, also known as elephant grass). Utilizing a greater proportion of above-ground plant material allows for higher production per unit of land area. Second-generation technologies also boast improved GHG and energy balances—both in terms of feedstock development and conversion technologies—and do not compete with food in the same way as first-generation feedstocks.

Table 4. Average Biodiesel Yields from Various First-generation Feedstocks

FEEDSTOCK	Fuel Yield (Liters biodiesel/ton feedstock)	Fuel Yield (Liters biodiesel /hectare)
Crude palm oil	230	4,900
Coconut	130	2,776
Jatropha	224	1,200
Rapeseed	392	1,188
Sunflower	418	954
Soybean	183	522

Source: FAO, 2008; Johnston et al, 2009

Table 5. Planted Area, Yield, and Total Production for Selected Biodiesel Feedstocks in Asia

CROP	COUNTRY	Area	Yield	Total Production
		Million hectares	Metric tons/hectare	Million metric tons
Soybean	China	9.2	1.8	16.7
Soybean	India	7.3	1.0	7.4
Rapeseed	China	7.1	1.8	12.8
Rapeseed	India	5.8	0.9	5.5
Oil Palm	Indonesia	4.6	17.0	78.0
Oil Palm	Malaysia	3.5	20.5	71.3
Oil Palm	Thailand	0.32	17.6	5.6
Oil Palm	China	0.05	13.9	0.69
Jatropha	With irrigation	NA	8	NA
Jatropha	Without irrigation	NA	2	NA

Source: FAOSTAT, 2009; Jatropha World, 2009

Note: Yields averaged between 2005 and 2008. Because jatropha is currently deployed on a small-scale, statistics on planted area and total production are not available. In most countries only a fraction of the total crop production is used for biodiesel production.

Cellulosic fuels are derived by one of two main pathways (Figure 4):

- **Biochemical:** in which enzymatic hydrolysis and lignin conversion use enzymes and other microorganisms to convert cellulose and hemi-cellulose into sugars via saccharification, which are then ready for alcohol fermentation.
- **Thermochemical:** in which one of two processes—gasification or pyrolysis—is used to produce fuels:
 - In gasification, biomass is reacted at high temperatures (upwards of 700 degrees Celsius) with controlled amounts of oxygen or steam to produce a synthesis gas or “syngas,” which is carbon monoxide and hydrogen. Syngas can be converted via what is known as the Fischer-Tropsch process to produce synthetic fuels such as synthetic diesel, gasoline, aviation fuel, and hydrogen. Dimethyl ether (DME) can also be produced from syngas, and can replace fossil fuel-based DME, liquid petroleum gas (LPG), cooking fuel, and diesel.
 - In pyrolysis, the biomass is heated in the absence of oxygen to produce organic liquids which must then undergo considerable refining to be used in engines.

In the case of the biochemical pathway, which produces lignocellulosic ethanol, breakthroughs are needed in the research and engineering of microorganisms designed to process specific feedstocks in addition to large-scale demonstrations to prove commercial viability. Ongoing research and development (R&D) is underway to isolate and identify enzymes that can be used in the biochemical pathway to separate and digest lignin. Some 10-20 years are probably required before commercial production could begin on a substantial scale (Larson, 2008). Enzyme hydrolysis could be expected to produce up to 300 liters of ethanol per dry metric ton of biomass (IEA, 2008b). Yields in liters per hectare depend on the metric tons of dry biomass produced per hectare. Switchgrass, for example, would produce roughly 1,000-3,000 liters of ethanol per hectare, and sugarcane residues could produce 4,000-6,000 liters of ethanol per hectare. In the case of sugarcane, this is in addition to the ethanol produced directly from the plant sugars.

The thermochemical pathway, also known as biomass-to-liquids (BtL), has an advantage over the biochemical pathway in that it converts all the organic parts of biomass, including the lignin—not just complex sugars—and produces a wide range of fuels, including replacements for gasoline and diesel and high-density fuels suitable for aviation and marine purposes. Many of the equipment components needed for biofuels production are commercially ready since they are already used in fossil fuel applications. Commercial production of thermochemical biofuels is possible within 5-10 years with adequate demonstration (Larson, 2008). Its main disadvantages are high start-up and maintenance costs and the need for large quantities of feedstock to reach optimal operational efficiencies (Gomez, et al., 2008). The Fischer-Tropsch route could produce 75-200 liters of synthetic diesel per dry metric ton of biomass and syngas-to-ethanol could yield 120-160 liters of fuel per dry metric ton (IEA, 2008b). In terms of fuel yield per hectare, switchgrass, for example, used to produce BtL fuels would yield 390-2220 liters of fuel per hectare, depending on switchgrass yields and the BtL pathway used. Similarly, oil palm residues could result in 340-900 liters of fuel per hectare, in addition to biodiesel produced from the oil palm fruit.

3.4 THIRD-GENERATION BIOFUELS

Third-generation biofuels are obtained from feedstock with better sustainability properties than second-generation biofuels. Currently, the most promising feedstock comes from microalgae, photosynthetic microorganisms of less than 0.4 mm in diameter that use sunlight, water, and carbon dioxide to produce algal biomass (Chisti, 2008). Algae can grow in ponds or photo bioreactors, or in hybrid systems that combine the two approaches, thus avoiding the need to use arable land. A photo bioreactor is essentially a bioreactor which incorporates a light source that the algae cycle through. Because these are closed systems, carbon dioxide, nutrient-rich water and light must be supplied. Water to grow algae can also be non-potable groundwater or municipal wastewater, which circumvents the demand for fresh water by first-generation—and second-generation—biofuels.

There are well over 100,000 species of algae, and some microalgae are much richer in oil than food crops currently

used to produce biodiesel, and have extremely high rates of efficiency in converting natural sunlight and CO₂ into fuel. For some species of algae, 80 percent or more of the dry weight of the algae's biomass can be recovered as oil, compared to 5 percent for some food crops (Chisti, 2007). In favorable conditions, microalgae grow very fast, doubling their mass within 24 hours to produce about 1.5 kg of algae biomass per cubic meter per day (Sanchez Miron, et al., 1999). Assuming an oil yield of 30 percent of the dry weight of algae biomass, a hectare could produce 98,000

liters of microalgae biodiesel per hectare, nearly 20 times the value of the next highest producing crop, oil palm, which generates approximately 4,900 liters per hectare (Chisti, 2008). Despite its remarkable promise, current cost estimates to produce oil from algae range from \$2.20 to \$22 per liter (Pate and Hightower, 2008). Further research is needed to make algae a viable commercial option. (See **Section 6.4** for additional discussion on specific technology challenges.)

SECTION 4

OVERVIEW OF THE GLOBAL BIOFUELS INDUSTRY

Over the past five years, the biofuels industry has experienced a brief period of explosive growth followed by a recent slump. Rapid growth in the US and EU biofuels sectors spurred similar growth in Asia, and many Asian countries have now set targets and mandates to continue to increase their biofuels production. Despite this growth, trade tariffs and a general lack of surplus production in Asia have kept trade volumes low. This section presents an overview of production trends and major producers; key international policies driving biofuels expansion, trade, and investments; and the current commercial status of the industry.

4.1 PRODUCTION TRENDS AND KEY PRODUCERS

Global production of biofuels tripled between 2004 and 2008, and an estimated 77 billion liters of ethanol and 12 billion liters of biodiesel were produced worldwide in 2008 (OECD-FAO, 2008). In Asia, in response to policy incentives and favorable economics, production of biofuels grew five-fold, from just over 2 billion liters in 2004 to almost 12 billion liters in 2008. Notably, biodiesel production went from virtually zero in 2004 to close to 1.8 billion liters by 2008 (Table 6). With these

Table 6. Current Biofuels Feedstocks and Total Production

COUNTRY	Currently Used Feedstocks		Ethanol Production (millions of liters)		Biodiesel Production (millions of liters)	
	Ethanol	Biodiesel	2007	2008	2007	2008
China	Maize/corn, wheat, cassava	Waste vegetable oil	5,564	6,686	355	355
India	Molasses	Jatropha, pongamia	2,450	2,562	45	317
Indonesia	Molasses, cassava	CPO	177	212	241	753
Malaysia	None	CPO	63	70	217	443
Philippines	Sugarcane	Coconut oil	62	105	257	211
Thailand	Molasses, cassava	CPO, waste cooking oil	285	408	0	48
Vietnam	Molasses, cassava	Animal fat (catfish oil) and used cooking oil	140	164	0	0
Total			8,741	10,207	1,115	1,772

Source: OECD-FAO, 2008; Milbrant and Overend, 2008a; Elder et al, 2008

Note: CPO = crude palm oil. Because official Chinese figures for biodiesel production were not available for 2008, 2007 levels were used. Ethanol figures represent total ethanol production. It is estimated that in most countries, fuel ethanol is one quarter to one third of the total production. OECD-FAO (2008) was chosen to ensure uniformity of data assumptions and data quality. Country level biofuels production estimates are available. However, they differ significantly from the OECD-FAO data. For example, OECD-FAO and the Ministry of Energy, Thailand, report biodiesel production in Thailand in 2008 to be 48 million liters and 400 million liters, respectively. Moreover, within a country official production figures differed. For example, two official sources within the Philippines estimated biodiesel production in 2008 to be 91 and 393 million liters, respectively, compared to an OECD-FAO estimate of 211 million liters. Readers are advised to treat these production volumes as relative values between the countries rather than absolute values.

dramatic increases, biofuels account for roughly 3 percent of the total transport fuel mix in Asia, based on data from country ministries and OECD-FAO (2008).

The United States, Europe, and Brazil produce about 90 percent of the world's biofuels (**Figure 5**). The United States and Brazil together account for 80 percent of total ethanol production in the world. The EU produces more than half the world's biodiesel, followed by the United States and Brazil. In Asia, India and China produce the majority of ethanol, and Indonesia and Malaysia are the largest biodiesel producers. Indonesia surpassed Malaysia in 2008 to become the world's largest palm oil producer at 18 billion liters; together, these two countries produce more than 80 percent of the world's palm oil (Naylor, 2007; OECD-FAO, 2008). In terms of the finished product, Malaysia and Indonesia together manufactured roughly 1.2 billion liters of biodiesel in 2008, making them the world's fourth and fifth largest producers, respectively (OECD, 2008). Roughly 10 percent of all palm oil is used for biodiesel production.

The ongoing economic downturn and low oil prices can be expected to have a dampening effect on overall demand for biofuels. In addition, the EU-imposed embargo on import of palm biodiesel from Southeast Asia can also be expected to lower biodiesel production in Asia (discussed

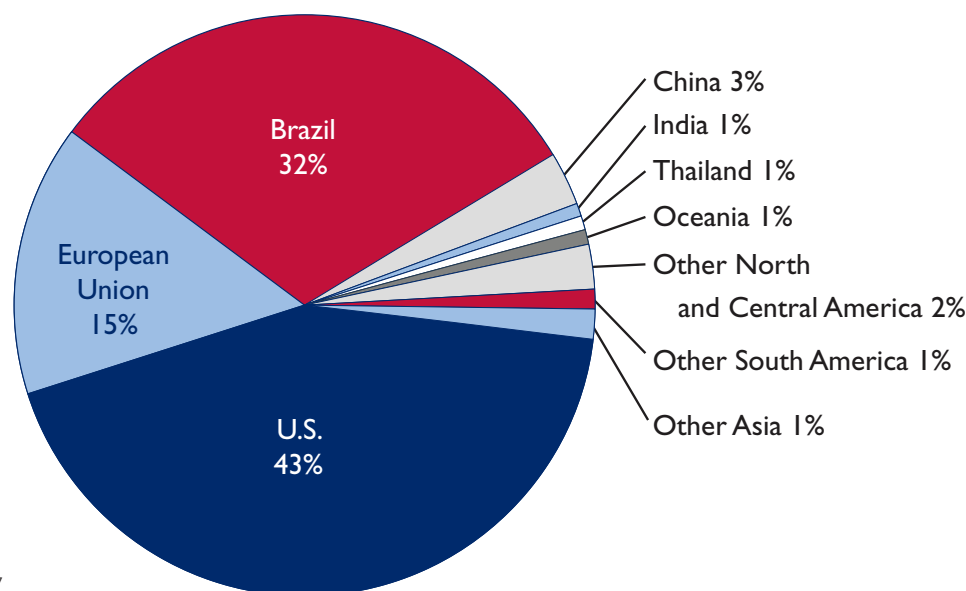
in **Section 4.2**). It is estimated that many plants in Indonesia and Malaysia have either shut down completely or are operating at 10-15 percent capacity (GSI, 2008c).

4.2 INTERNATIONAL POLICY DRIVERS

National policies and targets drive biofuels production by providing a support framework and incentives. Brazil began ethanol expansion in the 1970s with tax and financial incentives for sugarcane. Although Brazil has since scaled back subsidies, mandates and the favorable economics of production allow for a thriving domestic market and large export capacity. Mandates and targets established for biofuels in the EU and US expanded domestic production and led other countries to establish policies and incentives to pursue similar increases in biofuels production.

The EU Biofuels Directive of 2003, in particular, catalyzed the market by setting ambitious goals to promote biofuels and bioenergy, although revisions since then have created uncertainty in the marketplace. The EU originally set targets for biofuels to be 5.75 percent of transport demand by 2010 and 10 percent by 2020. High subsidies offered to biodiesel caused production to rise rapidly. By 2004, biofuels projects, especially biodiesel produced using

FIGURE 5. Global Share of Biofuels Production (2007)



Source: F.O. Licht in USDA, 2007

Note: Includes only ethanol for fuel

low-cost oil palm, sprouted up throughout Southeast Asia because Europe's aggressive policies were expected to lead to a shortage in biodiesel production capacity in the EU.

The EU has since reconsidered its mandates. Currently, EU targets aim to increase the share of biofuels in transport energy to 5 percent by 2015, of which 4 percent will come from agricultural biofuels and the remaining will come from other transport fuel alternatives. There will be an extensive review of biofuels targets in 2014 to assess how to set and achieve the 2020 target of 10 percent biofuels. In addition, agricultural first-generation biofuels will only count toward the target if they meet strict sustainability standards. Biofuels must provide a minimum of 45 percent GHG savings compared to fossil fuels—a figure that is expected to rise to 60 percent by 2015—subject to a review in 2014. This figure is much higher than the 35 percent savings originally proposed.

Under the 2007 US Energy Independence and Security Act, the Renewable Fuel Standard mandated a blend of 10.21 percent ethanol (42 billion liters annually) with gasoline by 2009 and introduced subsidies for biodiesel. The long-term goal is to expand ethanol use to 36 billion gallons (136 billion liters) annually by 2022. Half of the 2022 goal is to come from advanced biofuels (such as cellulosic fuels) that carry a GHG reduction of 50 percent or more (EPA, 2008). Other targets in the act include: (1) reducing GHG intensity by 18 percent from 2002 to 2012, (2) replacing 30 percent of transport fuel with biofuels by 2030, and (3) reducing gasoline consumption by 20 percent by 2017 through tighter fuel standards. However, the EIA predicts the US will fall well short of this target and critics have called for rollbacks on corn subsidies given that almost a third of the US corn crop is already being diverted to ethanol. The 2008 Farm Bill reduced the tax credit for corn-based ethanol from US\$0.51 to US\$0.45 per gallon (capping the credit at 15 billion gallons per year) and introduced a tax credit of US\$1.01 per gallon for cellulose-based ethanol starting in 2009 (US DOE, 2008). Several US states have established biofuels mandates; others are considering them. There also exists a long-standing biodiesel tax credit of \$1.00 per gallon, regardless of the feedstock, established in 2004, which was recently extended through December 31, 2009.

Countries in Asia are also instituting policies and incentives to increase demand for, and production of, biofuels. For example, Thailand established tax exemptions for ethanol that resulted in a 23-fold increase in consumption in 2005 alone (Elder et al., 2008). **Table 7** summarizes the current blending rates, targets, and other incentives in the focus countries and other relevant markets.

4.3 TRADE

Global trade in biofuels is currently low; only about one-tenth of the volume of biofuels produced is internationally traded (Kojima et al., 2007). Sources that track ethanol trade do not always differentiate between ethanol for fuel versus non-fuel uses, since tariffs are the same. In the analysis of trade figures below, fuel ethanol is assumed to be 40-50 percent of the total amount of traded ethanol, although in the case of China, two-thirds to three-quarters of ethanol traded is estimated to be related to the beverage industry (OECD, 2008b).

World ethanol trade was about 5 billion liters in 2006, with an estimated 3 billion liters traded annually in 2006 and 2007 (OECD, 2008a). At 3.5 billion liters annually, Brazil is the largest exporter (OECD, 2008a). At 1 billion liters annually, China is the second largest exporter, and exports ethanol from corn and wheat mainly to Japan, South Korea, and other Asian countries. Consumption targets make the United States the world's largest ethanol importer. It accounted for more than half of global ethanol imports in 2006, with more than half of that from Brazil. The EU is the second-largest importer, and also sources most of its imports from Brazil.

The global biodiesel trade accounted for about 12 percent of total biodiesel production in 2007. The EU and the US account for the bulk of this trade. The US, Malaysia, and Indonesia are the largest exporters of biodiesel. The EU is the largest importer, at more than 1.1 billion liters. The US imported large amounts of biodiesel for re-export to Europe because of a tax loophole that allowed for a blending credit of \$1 per gallon. However, Congress closed the so-called "splash and dash" loophole in 2008.¹ Indonesia and Malaysia exported about 800 million liters

¹ "Splash and dash" arose from a loophole in which US refiners imported biodiesel to blend with a "splash" of diesel to receive the \$1.00 per gallon tax credit, then "dash" the resultant B99 biodiesel blend to foreign markets, particularly Europe. Most of the biodiesel originated from Argentina and some from Indonesia. Biodiesel exports from Argentina crumbled at the end of 2008 as a direct consequence of this loophole being closed in May 2008. Now the credit is only offered to biodiesel that is manufactured and consumed in the US.

Table 7. Policies to Promote Biofuels in Asia and Other Markets

Country	Current Blend Rate		Future Mandates or Targets		Fiscal Incentives	Import Tariffs
	Ethanol	Biodiesel	Ethanol	Biodiesel		
China	E10 in 5 provinces and 27 cities	N/A	Increase to 3 MMT/yr by 2010, 10 MMT/yr by 2020	Increase to 300,000 MT/yr by 2010, 2 MMT/yr by 2020	Ethanol: Tax exemption, guaranteed pricing Biodiesel: R & D funding	Denatured ethanol: ad valorem 80% Undenatured: ad valorem 100% Biodiesel: ad valorem 20%
India	E5 in select states	B2.5, B5	Proposed: 20% biofuels in the transport mix by 2017; 11.2 mil ha of jatropha planted and matured by 2012 (not yet law)		Tax credits, subsidies for inputs, loans	Denatured ethanol: 253%-605% Undenatured ethanol: 52%
Indonesia	E5	B5	E5 by 2010 E10 by 2015 E15 by 2025	B10 by 2010, B15 by 2015, B20 by 2025	Total subsidy for biofuels: 33 trillion IDR; loan subsidies	No harmonized tariff rates Ethanol: Ad valorem 200%, Specific \$1.078/L
Malaysia	None	B5	No current policy	B5 nationwide by 2010	Plans to subsidize prices for biodiesel blends	No import tariff on biodiesel
Philippines	E10	B3	E5 by 2009 E10 by 2011	B2 in 2009 B5 in 2010	Exemption from specific tax and wastewater charge, priority financing,	Biodiesel: 3% Bioethanol: 1%
Thailand	E10 E20	B5	3 ML used per day by 2011; increased to 9 ML used per day by 2022; minimum E10 by 2011	B2 nationwide by April 2008, B5 by 2011, B10 by 2012	Tax breaks for ethanol; Exemption of 0.5-baht/L for biodiesel; government R&D	Denatured ethanol: 2.5baht/L Undenatured: 80 baht /L Biodiesel: ad valorem 5% Ban on palm oil imports
Vietnam	E5	None	500 ML by 2020	50 ML by 2020	None	NA
Japan	None		500 ML by 2010		Ethanol production subsidies	Ethanol: ad valorem import (23.8 %) duty lowered to 10% by 2010)
US	Range of blends	Range of blends	Use of 9 billion gallons of ethanol in gasoline in 2008, up to 11.1 billion gallons in 2009; proposed increase to 36 billion gallons by 2022		Ethanol Excise Tax Credit of \$0.45/gal to blenders; biodiesel blending credit of US\$1/ gal	Ethanol: ad valorem 2.5% + \$0.54 per gallon Biodiesel: ad valorem 6.5%
EU	Range of blends	Range of blends	5.75% of transportation fuel replaced with biofuels by 2010, 10% by 2020, 20% by 2030		45€/ha payment to energy crops grown on non-set-aside land	Biodiesel: ad valorem duty of 6.5% Ethanol: import tariff of €0.192/L (60% advalorem); subject to sustainability criteria
Brazil	E20 and up	B3	Mandatory E 20-25 (anhydrous ethanol)	Minimum B3 by July 2008; B5 by 2011	No direct subsidies	20% advalorem tariff on ethanol (waived in case of shortage)

Sources: APEC, 2008; IGES, 2008; FAO, 2008; Accenture, 2008; FAO, 2008

Note: CPO = crude palm oil; B# = percent of biodiesel mixed with conventional diesel; E# = percent of ethanol mixed with gasoline;
MMT = million metric tons; ML = million liters; ha = hectares

SECTION 4 OVERVIEW OF THE GLOBAL BIOFUELS INDUSTRY

of the 1.3 billion liters of biodiesel traded in 2007 (OECD, 2008a).

Historically, biofuels trade opportunities have been limited owing to the small competitive margin. In many countries, local biofuels production costs are often higher than import-parity prices for biofuels (e.g., Thailand) and equivalent petroleum fuels. Few countries other than Brazil have had the potential to be large exporters of ethanol or other biofuels (Kojima et al., 2007). The US and the EU have focused on production for domestic consumption.

Many countries that have set relatively high targets and mandates will be unable to meet their ambitious targets from domestic production alone.² For example, although the EU is a large producer of biodiesel, meeting its mandates will continue to require significant imports (Murphy, 2007). Tropical and subtropical countries can produce lower-cost biofuels because of greater land availability, ideal growing conditions, and lower labor costs. Because of these ideal production conditions, there could be a renewed push towards stimulating global trade in biofuels.

However, several barriers will need to be addressed. Trade opportunities are limited because many countries have established tariffs to protect their agriculture and biofuels industries. Import tariffs are relatively low in OECD countries, but high subsidies protect domestic production at the expense of lower-cost Asian producers. Other countries specifically restrict the biofuels trade. For example, the EU effectively cut off oil palm growers in Malaysia and Indonesia by introducing sustainability criteria, and Thailand banned palm oil imports to encourage local production.³

Trade prospects within Asia are also limited. Import tariffs are generally high (**Table 7**). To encourage its own biofuels industry, India has the region's highest import tariffs. Japan and Korea will likely remain Asia's main importers.⁴ Moreover, land and environmental constraints (discussed in **Section 5** and **Section 6**) will mean that only a limited number of countries would have any surplus to trade.

2 China, for example, is investing in Chinese-owned facilities in other countries, such as the Philippines, as a way of acquiring new sources of supply.

3 The World Trade Organization (WTO) has no plans to address biofuels trade barriers.

4 Although the Kyoto Protocol has not dealt with the biofuels trade, new trade opportunities may need to be pursued if multilateral commitments on climate change are expanded.

SECTION 5

POTENTIAL PRODUCTION OF BIOFUELS IN ASIA

This section presents an evaluation of the potential for biofuels production in Asia. The first analysis develops estimates for the potential production volumes that can be achieved if all the crop production that is currently lost on site during harvest (referred to as “wasted grain/crop”) were converted into ethanol using current technologies. The analysis indicates that wasted grain/crop, if recovered, can be converted into significant amounts of ethanol—ranging from 28 million liters to 5.3 billion liters annually—depending on the crop mix and the total extent of agricultural activity in each focus country. The second analysis estimates ethanol and biodiesel production potential over the next three decades from different feedstocks under various scenarios of land availability, agricultural yields, and residue utilization rates. Results of the analysis indicate that biofuels production by countries in the region can meet between 3 and 14 percent of total transport fuel demand in these countries. The extent to which production expansion materializes is contingent on infrastructure, processing facilities, and a significant expansion in feedstock production. Additionally, estimates of available land are uncertain and may be imprecise. In reality, land classified as “underutilized” or “degraded” may not be available. This assessment also does not account for water availability, a factor that could severely constrict the production of biofuels, particularly in India and China (see **Section 6**).

These potential production volumes are then compared with volumes required under the national mandates and targets that have been announced by the countries in order to estimate the extent to which the focus countries will be able to meet these mandates and targets. Not surprisingly, China and India have the greatest production potential since they possess the most available land, but neither country is projected to be able to meet its respective biodiesel mandate. China, India, Thailand, and Vietnam are expected to meet their ethanol mandates with steady growth in production but only Indonesia, Malaysia, and the Philippines are expected to meet their biodiesel targets.

5.1 PRODUCTION FROM WASTED GRAIN/CROPS

In most agricultural contexts, a proportion of harvested food grains and crops are wasted due to inefficiencies in collection, processing, and transportation. Kim and Dale (2004) estimate that for Asia, about 1–7 percent of various crops are wasted. Waste is highest for maize (7.1 percent), and relatively low for the sugarcane (1.1 percent). This wasted crop is suitable for ethanol production.

Estimates of total ethanol volumes that could be produced in each country from wasted crop were developed using data on harvested area, crop production, and yields for various food crops and cereals obtained from FAO’s database and from national ministries in each focus country.¹ Equation 1 presented in **Box 3** was used to make the calculations. The results presented in **Table 8** suggests that significant amounts of ethanol can be produced from grain/crops that are currently wasted. The amount varies from 28 million liters annually in Malaysia to 5.3 billion liters annually in China, and is determined by the crop mix and the total extent of agricultural activity in each country.

Ethanol production from wasted grain/crops—when expressed in terms of the percent of current overall gasoline demand in the country—ranges from a low of less than 1 percent in Malaysia to nearly 24 percent in India. Ethanol from wasted grain/crops could also address a significant percentage of current transport fuel demand in Thailand and Vietnam. It should be noted that it is unlikely that 100 percent of the wasted grain/crops can be recovered owing to logistical and cost challenges, and thus the results presented here should be considered the outer boundary of what may be feasible.

¹ These data were then averaged over the period from 2001 to the most recent year for which data were available, in order to minimize year-to-year variation.

Table 8. Potential Ethanol Production from Wasted Grain/Crops in Comparison with Gasoline Demand

COUNTRY	Potential Ethanol Production from Wasted Grain/Crop - Gasoline Equivalent (millions of liters)	Gasoline Demand in 2008 (millions of liters)	Potential Ethanol Production from Wasted Grain/Crops Compared to Gasoline Demand
China	5,309	79,306	6.7%
India	2,690	11,235	24%
Indonesia	856	17,645	4.9%
Malaysia	28	9,446	0.3%
Philippines	279	4,265	6.6%
Thailand	434	4,749	9.1%
Vietnam	482	4,362	11%

Source: ECO-Asia Clean Development and Climate Program

5.2 PRODUCTION FROM UNDERUTILIZED LANDS AND SECOND-GENERATION TECHNOLOGIES

The potential for biofuels production in 2009-2030 and beyond depends on a combination agricultural feedstocks, cultivated areas, and processing technologies. This analysis focuses primarily on two scenarios for increasing biofuels production over the next three decades. More detailed description of the calculations used for these scenarios is presented in **Box 3**.

Scenario One examines biofuels production potential from new, currently “underutilized” lands that support targeted, high-yielding first generation crops including sugarcane, cassava, and sweet sorghum for ethanol, and oil palm, coconut, and jatropha for biodiesel. This analysis assumes no use of existing agricultural land. The land sources for these crops, variously defined in the literature as open land, barren land, wasteland, area available for afforestation/pasture, or simply “other” land, are not expected to be as productive as currently cultivated croplands. Because these lands will likely be cultivated as demand for food, feed, and fiber grows, this analysis assumes that only a fraction of

the lands would be designated for biofuels and, even then, with varying levels of productivity. The combined ranges of land utilization and expected yield form the basis for the low, medium, and high estimates in the final results.

Scenario Two examines the potential for cellulosic ethanol production using advanced enzymatic hydrolysis and fermentation of cellulosic residues from current agricultural crops including maize, rice, sorghum, wheat, and sugarcane. However, to reflect the difficulty in collecting and transporting such an enormous quantity of low-value biomass, it is assumed that only small fractions of available residues would be processed, resulting in the low, medium, and high estimates in the final results.

Significant R&D is taking place on new processing technologies such as gasification and pyrolysis, as well as on new biofuels feedstocks such as microalgae and non-commercialized native plant species. However, since these technologies are not expected to be commercial in the near term (5-10 years), it is most likely that countries in Asia will prioritize implementation of the scenarios outlined here due to their reliance on well-established or rapidly expanding agricultural feedstocks, and the desire to reduce the risk for farmers in the near term (Sims et al., 2008).

Table 9 presents the assumptions about crop mix, area planted, yield, and the percentage of available residue that is processed that were used to generate the low, medium, and high estimates for production under each scenario. The scenarios outlined below can be realized independently or in conjunction due to their reliance on different agricultural feedstocks and cultivated areas.

The implementation of Scenario One, based on existing processing technologies, can begin almost immediately with appropriate policies and capital expenditures (and is underway in many countries). In contrast, Scenario Two relies on advances in cellulosic ethanol technologies that delay implementation for 10 years. The biofuels potential presented in this study could follow many different development paths. **Figure 6** shows a path representing the most aggressive pursuit of the two scenarios.

SCENARIO ONE

AREA COVERAGE

Land classifications and related data for Scenario One were obtained from multiple sources, namely the FAO database (FAOSTAT), Bhattacharya et al. (2003), and national ministry or country databases in the focus countries where available, and compared. The different sources vary in terms of their definitions and estimates for underutilized land in each country (**Table 10**).² Total available land values for each country were taken from either Bhattacharya et al.

(2003) or from country-specific sources, depending on which were more conservative.

It is expected that some of these underutilized lands will be brought under cultivation in the near future to meet the food, feed, and fiber demands of a growing population. Additionally, some of this land is expected to be unusable for cultivating any crops, regardless of their use. Therefore, calculations for Scenario One assume only 1 percent, 2.5 percent, or 5 percent of the total available lands for the low, medium, and high ranges.

CROP-MIX AND PLANTING-RATIOS

When expanding cultivated areas with the explicit intent of growing crops for biofuels, it is prudent to prioritize crops with high-energy yields per hectare. Based on crops included in national strategies for various countries and published assessments by regional bodies such as Asia-Pacific Economic Cooperation (Milbrant and Overend, 2008b; OECD-FAO, 2008), this study selected six crops for expansion into underutilized lands.

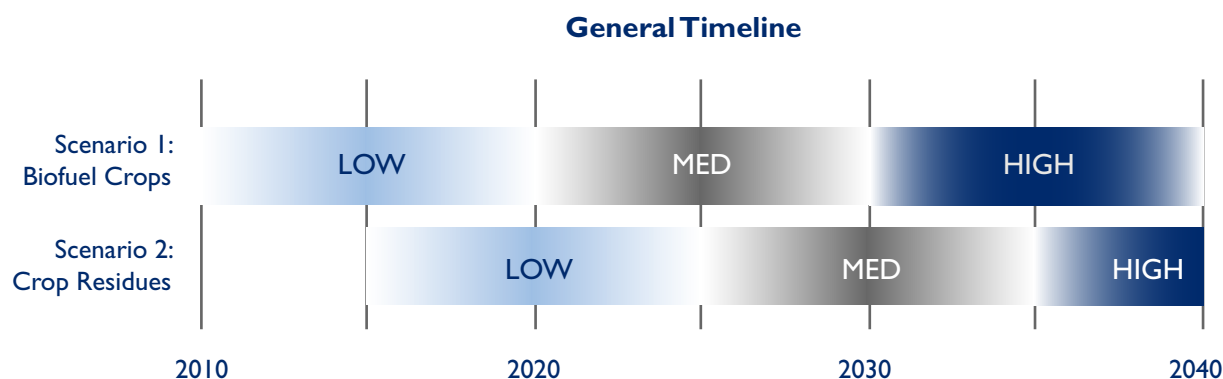
Table 11 lists the crop-mix for each country under Scenario One.

Numerous biophysical factors influence the success of a crop on a parcel of land, including soil type and quality, water availability, and climate. The exact crop ratios and priorities for each country will likely differ from what

Table 9. Scenarios for Modeling Production Potential on Underutilized Lands and for Second-Generation Biofuels

DESCRIPTION	Crop-Mix	Area	Yields
Scenario 1: High-yielding first generation crops on underutilized lands	Ethanol: sugarcane, cassava, and sweet sorghum. Biodiesel: oil palm, coconut, and jatropha	1%, 2.5%, or 5% of underutilized lands to reflect quality and competition concerns of available lands	10th, 20th, or 30th percentile of current yields to reflect lower productivity of potentially degraded lands
Scenario 2: Cellulosic ethanol from grain and sugarcane crop residues from existing agricultural lands	Ethanol: maize, rice, sorghum, sugarcane, and wheat	5%, 10%, or 15% of existing crop lands to reflect inherent challenges to transporting residues, and soil fertility concerns	Current average agricultural yields

² For example, in the case of China, estimates of available land vary from 75 million hectares to more than 300 million hectares. Similarly, in the case of the Philippines, estimates of available land vary from 300,000 to more than 5 million hectares.

FIGURE 6. Timelines for Realization of Scenarios One and Two (2010–2040)

is presented here. Without knowing the location and condition of underutilized lands, these crop ratios are assumed to be distributed over available land for several target crops.

YIELDS

Using the methodology in Johnston et al. (2009), estimates of biofuels yield per hectare were calculated for four of

the six target crops—cassava, sugarcane, oil palm, and coconut—for each country. These calculations are based on a dataset from Monfreda et al. (2008) called the “M3 cropland dataset,” which combines roughly 22,000 agricultural censuses reporting units from around the world with a recent map of global croplands, thereby producing spatial yield and area coverage maps for 175 crops. Using this methodology, accurate yield ranges were calculated as opposed to using a single number for each country-crop combination.³ For this study, the tenth-, twentieth- or thirtieth-percentile biofuels yields reflect varying levels of productivity on newly cultivated lands, and correspond to the low, medium, and high estimates in Scenario One. The lower-than-average values reflect the potentially lower quality of the lands in question. Yield estimates for sweet sorghum and jatropha, two crops that are not widely commercialized and not included in the FAO or M3 datasets, were compiled from a variety of references.⁴

PRODUCTION POTENTIAL

Biofuels production potential for each country under Scenario One was calculated using Equation 2 (see **Box 3**).

Table 10. Land Classifications and Estimates of Available Land in Focus Countries (1 000 hectares)

COUNTRY	Available Land	Source
China	75,000	Bhattacharya et al. 2003
India	14,200	Bhattacharya et al. 2003
Indonesia	16,669	Data from Country Ministries
Malaysia	980	Bhattacharya et al. 2003
Philippines	5,120	Bhattacharya et al. 2003
Thailand	18,690	Bhattacharya et al. 2003
Vietnam	8,425	Data from Country Ministries

3 The M3 cropland datasets record area coverage and yield performance for circa the year 2000, averaged over several prior and subsequent years to minimize variability. The base year of this study is 2010. Using FAO yield trends for each crop-country combination, M3 cropland yields were extrapolated to 2010.

4 Multiple-year results from six different cultivars of sweet sorghum-based ethanol were averaged in Bennett et al. (2009), with a reported maximum ethanol yield of 6,366 liters per hectare, a minimum of 2,365 liters per hectare, and an average of 4,112 liters per hectare. Reported jatropha-biodiesel yields ranged from a maximum of 2,470 liters per hectare to a minimum of 464 liters per hectare across three sources (Foidl et al., 1996; de Fraiture et al., 2008; Prueksakorn and Gheewala, 2008). However, one source cited a much lower maximum yield of approximately 1,500 liters per hectare, which was used for this analysis to maintain conservative estimates (de Fraiture et al., 2008). To remain consistent with the above ranges of potential crop yields, the minimum value in each case was chosen as the tenth-percentile yield, 75 percent of the maximum reported yield was chosen as the thirtieth-percentile yield, and the average of the two was used as the twentieth-percentile biofuels yield.

Table 11. Crop-mix and Planting-ratio Assumed for Expansion on Underutilized Land

CROP-MIX		China	India	Indonesia	Malaysia	Philippines	Thailand	Vietnam
Ethanol	Cassava			33%			33%	33%
	Sugarcane		50%	33%			33%	33%
	Sweet Sorghum	85%						
Biodiesel	Coconut					50%		
	Jatropha	15%	50%			50%		33%
	Oil Palm			33%	100%		33%	

Table 12. Area of Existing Croplands Used to Calculate Biofuels Potential from Crop Residues (1,000 hectares)

CROP-MIX	China	India	Indonesia	Malaysia	Philippines	Thailand	Vietnam
Maize	25,293	7,316	3,364	24	2,507	1,053	943
Rice	28,732	43,122	11,745	669	4,104	10,137	7,408
Sorghum	665	9,134	22			53	
Sugarcane	1,335	4,278	357	15	386	1,023	294
Wheat	22,991	26,201					

Source: FAOSTAT, 2008; Country Ministries

SCENARIO TWO

AREA AND CROP-MIX

Scenario 2 is based on five staple crops—maize, rice, sorghum, sugarcane, and wheat—and the ability to process residues from these crops into ethanol using advanced enzymatic hydrolysis (which is not yet commercialized) and fermentation. To calculate total agricultural residues available for conversion, FAO estimates of the land cultivated for the target crops (FAOSTAT) were multiplied by a residue fraction for each crop (**Table 12**).

YIELDS

Calculations for production potential from crop residues assume existing crop yields and production. Due to the

low value and high volume of agricultural wastes, collection and processing is only expected to be profitable in certain agriculturally dense areas. In addition, some portion of the crop residues needs to be tilled back into the soil to maintain its fertility and reduce the need for fertilization. To reflect the complexities of harvesting and transporting crop residues, only 5 percent, 10 percent, or 15 percent of total available residues are assumed to be recoverable for processing into ethanol. This also addresses the need to retain much of the residue on site to maintain long-term soil fertility.

PRODUCTION POTENTIAL

Biofuels production potential for each country under Scenario Two was calculated using Equation 3 (see **Box 3**).

Box 3. Calculations Used to Generate Various Estimates of Potential Production Volumes**EQUATION 1. POTENTIAL BIOFUELS FROM WASTED GRAIN/CROP**

For a given crop, percentages of wasted grain/crop were assumed to be the same across all the countries. Equation 1 was used to calculate possible bioethanol production from a given crop.

$$BPwc_i = BF_{yi} \times WC_{BFi} \times PR_{avi}$$

$BPwc_i$ = Quantity of biofuels production (million liters) from wasted grain/crop; BF_{yi} = Biofuel yield from grain/crop (liters/kg); WC_{BFi} = Percentage of wasted grain/crop; PR_{avi} = Average crop production (1000 tons); i = Crop

The potential ethanol production from wasted grain/crops is the product of the biofuels yield from the crop, the percentage of wasted crop, and the average crop production. Total potential biofuels production in a country is the sum of production from the various crops grown in that country.

Total possible ethanol production from wasted grain/crops = $\sum BPwc_i$

EQUATION 2. POTENTIAL PRODUCTION IN SCENARIO ONE

Equation 2 was used to calculate the biofuels production potential in Scenario 1 where:

$$Pi = \sum_{j=1}^{\# crops} AJ * Yj \qquad Ai = \sum_{j=1}^{\# crops} AJ$$

For each country (i) and crop (j), biofuels production volume (P) is equal to the area (A) allotted to each crop multiplied by the yield (Y), such that the area of all individual crops totals the area of the available land designated by the study for each country. These calculations were repeated three times, to develop the low, medium, and high estimates of area and yield outlined above.

EQUATION 3. POTENTIAL PRODUCTION IN SCENARIO TWO:

Equation 3 was used to calculate the biofuels production potential in Scenario Two:

$$Pi = \sum_{j=1}^{\# crops} CPij * RPRj * RPi * RYj$$

For each country (i) and crop (j), the volume of biofuels production (P) equals the product of the average crop production (CP), the residue-to-production ratio (RPR), the percentage of residue available for biofuels production (RP), and the biofuels yield for that particular residue (RY). These calculations were repeated three times, to develop the low, medium, and high estimates of area and yield.

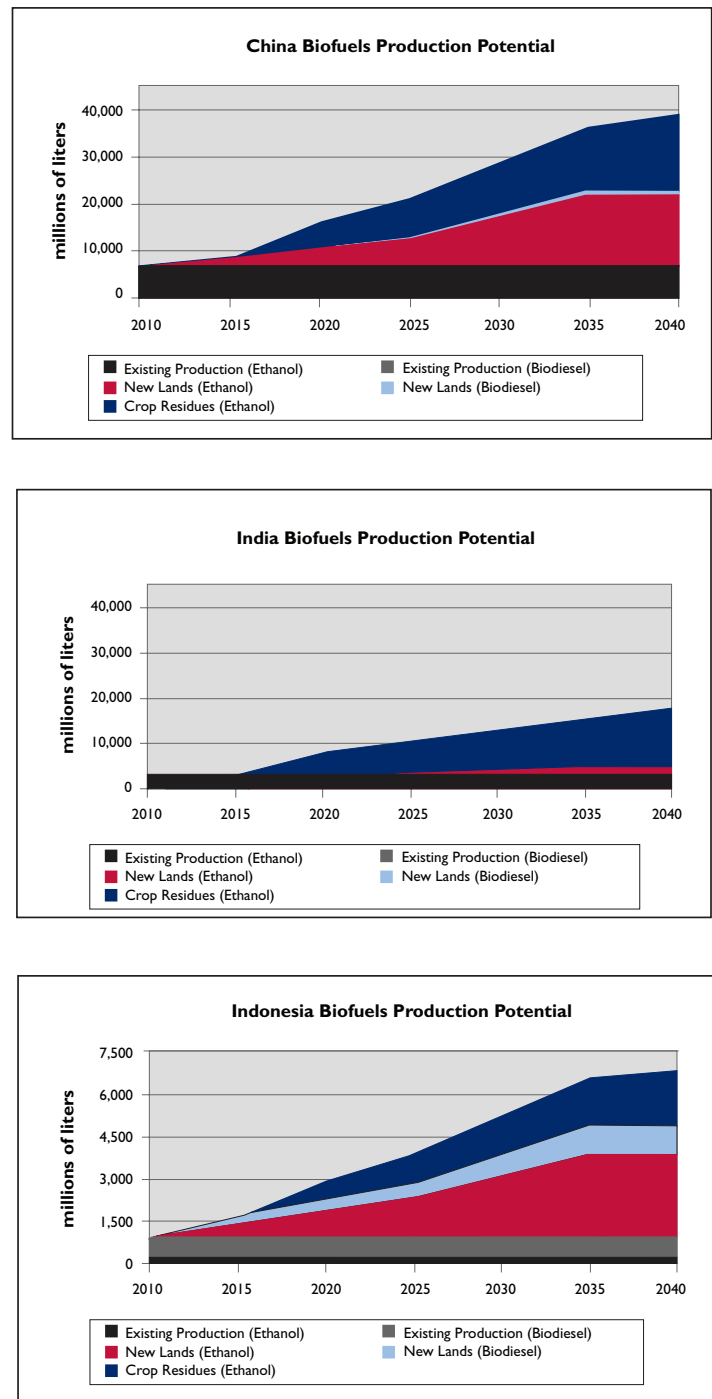
5.3 TOTAL PRODUCTION POTENTIAL FOR BIOFUELS

Figure 7 shows potential biofuels production from underutilized lands (referred to as “new lands”) and crop residues (Scenarios One and Two, respectively) in the focus countries stacked on top of the current ethanol and biodiesel production in that country⁵ (the “baseline status”). Current production is assumed to stay constant as countries avoid additional production from current agricultural lands in favor of production from underutilized lands, and from crop residues.

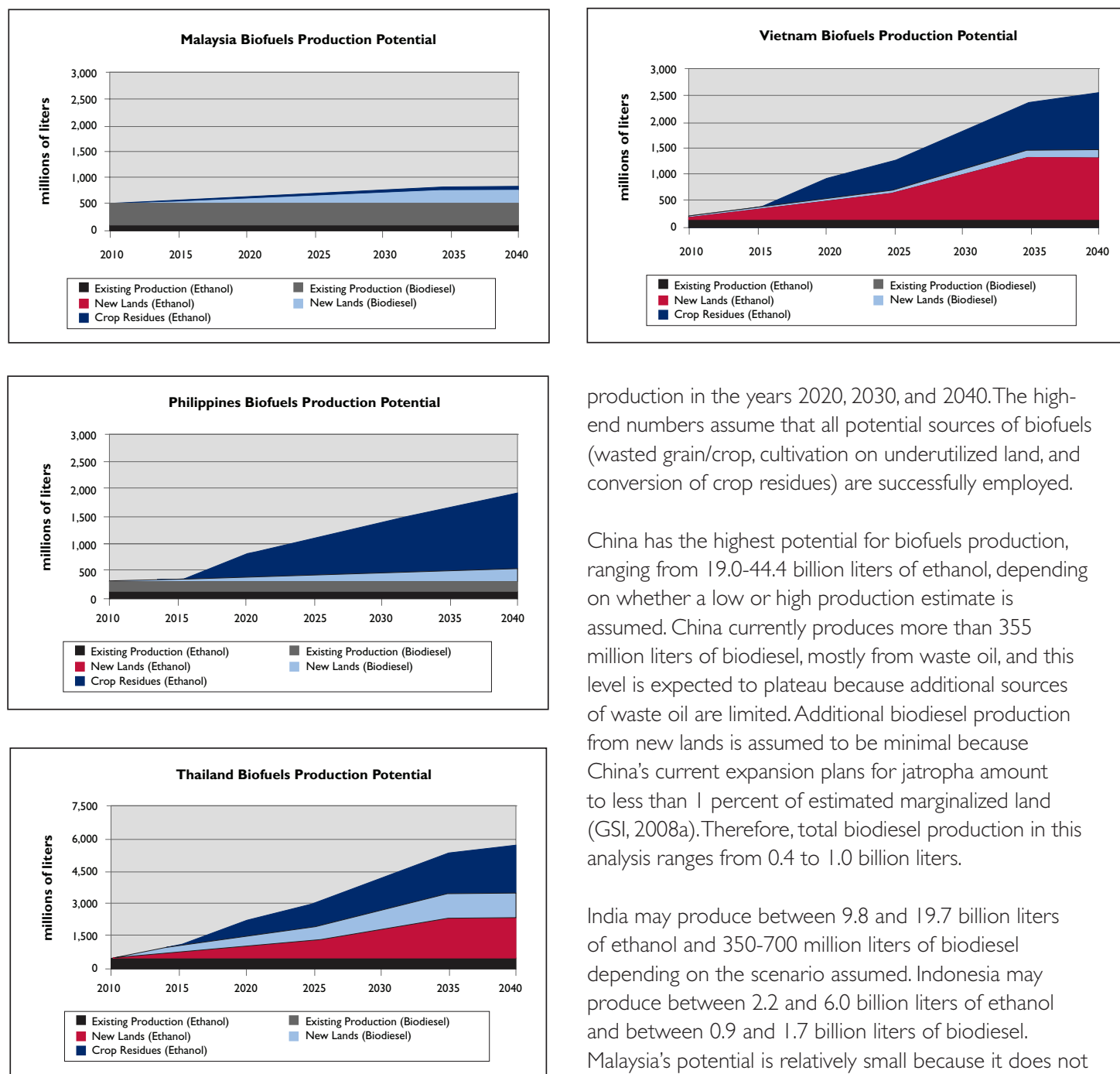
The timeline of these country graphs corresponds with **Figure 6**, which outlines the most aggressive possible pursuit of the two scenarios. Efforts to reclaim underutilized lands for biofuels production could theoretically begin immediately, with countries starting to realize sizable production in 2015, which corresponds with the low range of Scenario One. The Scenario Two development path could be pursued independently of Scenario One. Assuming the necessary breakthroughs in cellulosic processing and costs, a country might expect ethanol production corresponding with the “low” range of Scenario Two by approximately 2020. If commitments to increase use of underutilized lands for biofuels and to process agricultural residues are made and kept, each scenario could progress from its low, to medium, and finally to high estimates in the coming decades.

Each country has a different potential in each scenario depending on the local crop-mix, area utilized, and amount of residues available for processing. For example, Malaysia holds more potential from cultivating underutilized lands (Scenario One) than from collecting and processing crop residues and wastes from existing crops (Scenario Two). This is because oilseeds, which offer scant residues for processing into ethanol, currently dominate agricultural production in Malaysia. In contrast, India and the Philippines, which grow more staple grain and sugarcane, hold more potential from the processing of residues in comparison to production from underutilized lands. China, Thailand, and Vietnam fall in the middle, producing roughly equal amounts of ethanol from underutilized lands and from residues in each country.

FIGURE 7. Low, Medium, and High Estimates of Biofuels Production from Scenarios One and Two



⁵ Current production as presented in Table 6, Section 4.

FIGURE 7. Low, Medium, and High Estimates of Biofuels Production from Scenarios One and Two

production in the years 2020, 2030, and 2040. The high-end numbers assume that all potential sources of biofuels (wasted grain/crop, cultivation on underutilized land, and conversion of crop residues) are successfully employed.

China has the highest potential for biofuels production, ranging from 19.0-44.4 billion liters of ethanol, depending on whether a low or high production estimate is assumed. China currently produces more than 355 million liters of biodiesel, mostly from waste oil, and this level is expected to plateau because additional sources of waste oil are limited. Additional biodiesel production from new lands is assumed to be minimal because China's current expansion plans for jatropha amount to less than 1 percent of estimated marginalized land (GSI, 2008a). Therefore, total biodiesel production in this analysis ranges from 0.4 to 1.0 billion liters.

India may produce between 9.8 and 19.7 billion liters of ethanol and 350-700 million liters of biodiesel depending on the scenario assumed. Indonesia may produce between 2.2 and 6.0 billion liters of ethanol and between 0.9 and 1.7 billion liters of biodiesel. Malaysia's potential is relatively small because it does not have much land for expansion or residues. As a result, potential production is between 120 and 165 million liters of ethanol and between 500 and 700 million liters of biodiesel. The Philippines can produce between 0.8 and 1.7 billion liters of ethanol and between 240 and 430 million liters of biodiesel. Thailand is expected to be able to produce 1.9-4.9 billion liters of ethanol and 0.3-1.2 billion liters of biodiesel by 2030. Vietnam's

Table 13 presents the aggregate potential for biofuels production in each country. Current production plus potential ethanol production from wasted grain/crops (**Section 5.1**) are shown alongside the potential from crop residues and new lands according to the low, medium and high production estimates that correspond to projected

Table 13. Total Biofuels Production Under Low, Medium and High Scenarios to 2040
(millions of liters)

COUNTRY	Existing			Low Scenario			Medium Scenario			High Scenario			Total Potential (Existing + Wasted grain/ crop + High Scenario)
	Ethanol	Biodiesel	Ethanol	Ethanol	Biodiesel	Ethanol	Ethanol	Biodiesel	Ethanol	Ethanol	Biodiesel	Ethanol	
China	6,686	355	5,309	1,508	52	5,389	5,905	224	10,778	15,220	633	16,167	44,370
India	2,562	317	2,690	215	33	4,350	639	141	8,700	1,407	399	13,050	20,426
Indonesia	212	753	856	563	144	660	1,450	495	1,320	2,940	990	1,980	7,731
Malaysia	70	443	28	0	37	22	0	124	44	0	249	66	855
Philippines	105	211	279	0	27	460	0	89	919	0	220	1,379	2,194
Thailand	408	48	434	330	236	717	867	590	1,433	1,885	1,181	2,150	6,105
Vietnam	164	0	482	194	13	364	515	56	729	1,165	158	1,093	3,062
	Existing Crops		Wasted Grain/Crop	New Lands		Residues	New Lands		Residues	New Lands		Residues	
	Sources of Feedstock												

Source: Estimates for existing production are from OECD-FAO, 2008.⁶ All other data is from ECO-Asia Clean Development and Climate Program.

emerging biofuels industry has the potential to produce 1.2-3.0 billion liters of ethanol and 10-160 million liters of biodiesel.

Comparing the medium growth scenario for biofuels production in each focus country (corresponding to 2030) with the respective medium growth scenario for transport fuel demand in 2030 (**Table 1, Section 2**), it is estimated that countries in the region will be able to produce enough biofuels by 2030 to meet between 3 and

14 percent of total transport fuel demand. Thailand has the highest potential for transport fuel displacement at about 14 percent of total fuel demand by 2030. Malaysia's biofuels production potential is relatively small because it has a limited amount of land for expansion and limited crop residues. Its potential production is just 3 percent of total transport fuel demand. India is estimated to be able to displace about 12 percent of its transport fuel demand by 2030, and Indonesia's potential production could contribute up to 11 percent of total transport fuel demand.

⁶ This source was chosen to ensure uniformity of data assumptions and data quality. It should be noted that in most cases, data from OECD-FAO differed significantly from country-level data sources from ministries. For example, OECD-FAO and the Ministry of Energy, Thailand, report biodiesel production in Thailand in 2008 to be 48 million liters and 400 million liters, respectively. Similarly, in the case of Malaysia, OECD-FAO and the Malaysian Biodiesel Association, report biodiesel production in 2008 to be 443 million liters and 200 million liters, respectively. Often different government sources within a country differ in their reported values for biofuels production. Official government biodiesel production figures for the Philippines range from 91 to 383 million liters. Given these data-related challenges, it was considered prudent to use a consistent data set published by the OECD-FAO. Readers are cautioned that the values for existing production should be viewed not in absolute but in relative terms. The choice of data source does not change the overall trends or conclusions presented or whether countries will meet their mandates (Section 5.4). For example, in the case of biodiesel, whether Thailand's 2008 biodiesel production is 48 million liters or 400 million liters does not change the fact that they are unlikely to meet their biodiesel target in 2012. Similarly, in the Philippines, country figures for 2008 ethanol production ranged from 39 million liters to 105 million liters but regardless of which figure, the Philippines is still unlikely to meet its ethanol mandate. Different country-level biofuels production estimates are included for reference in Annex 1: Country Profiles.

Table 14. Future Demand and Production of Ethanol in the Focus Countries
(millions of liters)

COUNTRY	Target year	Scenario	Blending mandate / target	Gasoline demand in target year	Ethanol required	Production in target year				TOTAL	Target achievable?
						Current production	Ethanol from wasted grains/ crop	From new lands	From crop residues		
China	2020	Medium	10 MMT	113,072	12,700	6,686	5,309	5,905	10,778	28,678	YES
India	2017	Low	20%	15,312	3,062	2,562	2,690	215	4,350	9,817	YES
Indonesia	2015	Medium	20%	22,269	4,054	212	856	1,450	1,320	3,838	NO
Philippines	2011	Low	10%	4,660	466	105	279	0	0	384	NO
Thailand	2011	Low	10%	4,893	489	408	434	330	0	1,172	YES
Vietnam	2020	Medium	500 ML	6,592	500	164	482	355	729	1,730	YES

Source: ECO-Asia Clean Development and Climate Program; OECD-FAO, 2008 for current production numbers.

Both the Philippines and Vietnam are estimated to be able to displace roughly 8 percent of their respective total transport fuel demands. China is expected to be able to offset total transport fuel demand by 6 percent by 2030.

5.4 THE POTENTIAL FOR BIOFUELS PRODUCTION TO MEET NATIONAL MANDATES AND TARGETS

Based on the projections of liquid fuel demand in Asia derived in **Section 2**, and the potential biofuels production estimates developed in **Section 5.3**, it is possible to estimate whether the focus countries would be able to meet their stated future blending mandates or targets.

The blending mandates announced by the seven focus countries vary widely. China and Vietnam, for example, have stipulated absolute volumes of biofuels that must be produced by a given date, whereas the other countries have specified biofuels targets as a percentage of total transportation fuel requirements. Most countries have separate target dates and mandates for ethanol and biodiesel, although India has set a provisional overall target

at 20 percent. In India's case, this analysis assumes equal targets for both ethanol and biodiesel. Some countries (Thailand, Malaysia, and the Philippines) have very near-term blending mandates, while others (China, India, and Vietnam) have taken a much longer-term view. Despite the variance in the structure and implementation of blending mandates, this exercise provides a primary assessment of the extent to which the goals of the focus countries can be met.

Table 14 and **Table 15** compare each country's current and expected biofuels production with the levels of production required to meet its mandates or targets, and indicates whether the mandates—for both ethanol and biodiesel—can be met. For each country, only the combination of scenarios most likely to occur at or near the target date for the blending mandate is considered. For target dates before 2020, the “low” combination of scenarios is used (i.e., 1 percent of available land converted into cropland, 10th percentile of current agricultural yield, and only 5 percent of available waste recovered for processing into ethanol). For 2020 and beyond, the “medium” combination of scenarios is used (i.e., 2.5 percent of available land converted into cropland, twentieth-

Table 15. Future Demand and Production of Biodiesel in the Focus Countries
(millions of liters)

COUNTRY	Target year	Scenario	Blending mandate / target	Diesel demand in target year	Biodiesel required	Production in target year		TOTAL	Target achievable?
						Current production	From new lands		
China	2020	Medium	2 MMT	225,134	2,400	355	224	579	NO
India	2017	Low	20%	64,706	12,941	317	33	350	NO
Indonesia	2010	Medium	10%	11,593	1,159	753	495	1,248	YES
Malaysia	2010	Low	5%	6,466	323	443	-	443	YES
Philippines	2009	Low	2%	5,967	119	211	-	211	YES
Thailand	2012	Low	10%	17,338	1,734	48	236	284	NO
Vietnam	2020	Medium	50 ML	11,541	50	-	34	34	NO

Source: ECO-Asia Clean Development and Climate Program; OECD-FAO, 2008 for current production numbers.

[a] All figures in million liters (ML) unless noted otherwise.

[b] Projections for fuel demand in the target year may differ from country-level estimates because ECO-Asia Clean Development and Climate Program fuel demand estimates are extrapolations of current consumption levels.

[c] China's and Vietnam's mandates are not given in percentage terms but as absolute volumes. China's targets are in million metric tons; Vietnam's targets are in million liters.

[d] India's proposed mandate is 20 percent biofuels by 2020 (i.e., it does not specify separate mandates for ethanol and biodiesel). Here, the 20 percent mandate for both types of biofuels is applied. Realistically India would attempt to fulfill the mandate with mostly ethanol because of its greater production potential, even though diesel consumption accounts for a greater portion of total transport fuel demand.

percentile of current agricultural yield, and 10 percent of available waste recovered for processing into ethanol). Similarly, the medium-growth outlook is used for transport fuel demand in each country as a reference point. For countries with targets within the next five years, no ethanol production from crop residues was assumed.

Overall, the tables suggest that four out of six countries with ethanol mandates will be able to meet their targets if production is scaled up consistently.⁷ Four out of seven

countries will be unable to meet their biodiesel targets. No country is able to achieve mandates for both ethanol and biodiesel. Where production falls short of the mandated demand, the required biofuels may need to be imported, or the mandate itself may need to be revised.

Table 14 also shows that all countries with ethanol mandates, except Indonesia and the Philippines, could produce surplus ethanol that can be traded regionally, if adequate trading mechanisms and biofuels specifications are established within the next decade.

⁷ Malaysia does not currently have an ethanol mandate.

SECTION 6

SUSTAINABILITY ASSESSMENT OF BIOFUELS

6.1 ENVIRONMENTAL SUSTAINABILITY

6.1.1 LIFE CYCLE ASSESSMENT

A life cycle assessment (LCA) is a holistic inventory of the environmental impacts of a given product along its production chain, including relevant energy and material inputs and environmental discharges. This section presents LCA data in terms of net energy balance and GHG savings for a selection of feedstocks used to produce biofuels in Asia. Net energy is the balance between energy expended and energy gained in the production of one unit of fuel. The GHG balance of a biofuels refers to the net amount of GHGs emitted during the life cycle relative to fossil fuels. The extent of net energy and GHG benefits varies by feedstock, the location where it is grown, and fuel production process, including the use of co-products and wastes.¹ The goal of assessing the full range of environmental impacts is to be able to choose feedstocks with the best net environmental benefits.

The analysis evaluates production processes under best- and worst-case conditions for ethanol produced from sugarcane, corn, cassava, sweet sorghum, and lignocellulosic feedstocks, and for biodiesel produced from oil palm, jatropha, and coconut. Best-case production conditions assume low agricultural inputs (i.e., water, fertilizers and pesticides), no land use change, utilization of co-products and waste recovery. Worst-case conditions assume a high degree of agricultural inputs, severe land use change, low use of co-products and no waste recovery. The degree of land use change and use of co-products are the most important factors in overall environmental performance.

The production systems for *sugarcane*, *sweet sorghum*, and *cellulosic-based ethanol* have the best net energy and GHG balances, assuming plantation on degraded land. For biodiesel production systems, *oil palm* and *jatropha*, when planted on degraded land, present the best net energy and GHG balances, although coconut also has positive environmental impacts. While *palm oil* has the highest GHG savings when planted on degraded land, it should be noted that, in reality, oil palm plantations are seldom planted on degraded lands. Under worst-case production conditions, all feedstocks have poorer net energy and GHG balances. Even the most productive feedstocks deliver an unacceptably negative GHG balance when established on carbon-rich soils, such as peatlands.

DESCRIPTION OF THE SYSTEM BOUNDARY

The system boundary of the LCA defines what is included in the assessment of the various steps in biofuels production, including biofuels feedstock production, processing, utilization, and disposal and all intervening transportation steps (**Figure 8**). The factors evaluated for each feedstock's production chain include:

- land use change;
- agricultural methods for the production of feedstocks (e.g., fertilizers consumed);
- conversion processes to turn feedstocks into biofuels, including whether co-products, waste products, and waste energy are utilized;
- transportation; and fossil fuel consumed throughout the production chain (as process energy).

¹ There is considerable debate over how to conduct LCA studies as well as what factors to include. Many studies do not include land-use change for example. There is also variation in how the results are presented. Studies generally calculate net energy as either a balance (net MJ per unit of fuel, as is used in this report) or as a net energy ratio (MJ of fuel energy available/MJ of input energy). When using a ratio, values greater than 1 mean the fuel is sustainable, values less than 1 indicate more energy is consumed in the production process than is available in the final fuel. Some biofuels can have net energy ratios of less than 1 because a large amount of energy is consumed to produce it. From a sustainability standpoint, if the net energy ratio is less than 1 but most of the fuel consumed is renewable (e.g., ethanol used in transport, or bagasse co-fired for electricity) the impact is less than when the net energy ratio is less than 1 and the process energy is exhaustible fossil fuel, as can often be the case with corn-based ethanol. Similarly, net GHGs can be calculated as a GHG savings value (total GHGs per unit of gasoline equivalent fuel) or as a net value (total GHGs per unit of gasoline equivalent fuel minus the total GHGs per unit of gasoline or diesel). A low GHG value or a net GHG value of less than zero is desirable from a sustainability perspective. (Rajagopal, 2009)

To analyze net energy and GHG balances, ethanol and biodiesel production systems were compared to a baseline fossil fuel production system—comprising extraction, transport to refinery, refining (accounting for co-products), delivery, and use in combustion systems. Against this baseline, the best-case production conditions for both ethanol and biodiesel production systems generally assume low fertilizer and pesticide inputs; plantation on degraded lands; optimal process efficiency; utilization of co-products, most notably the burning of crop residues to provide process energy and the use of by-products as fertilizer; and the treatment of wastes. Worst-case conditions assume high fertilizer and pesticide inputs; land use change that replaces native vegetation (primarily forests and grasslands); poor process efficiency; poor co-product utilization and no treatment of wastes. As illustrated in **Figure 8**, land use change can have the largest effect on net GHG emissions. (It does not impact the net energy balance.) The use of co-products is also an important best practice that will minimize environmental impact from both a net energy and GHG perspective. Further details on the calculations and parameters that characterize the

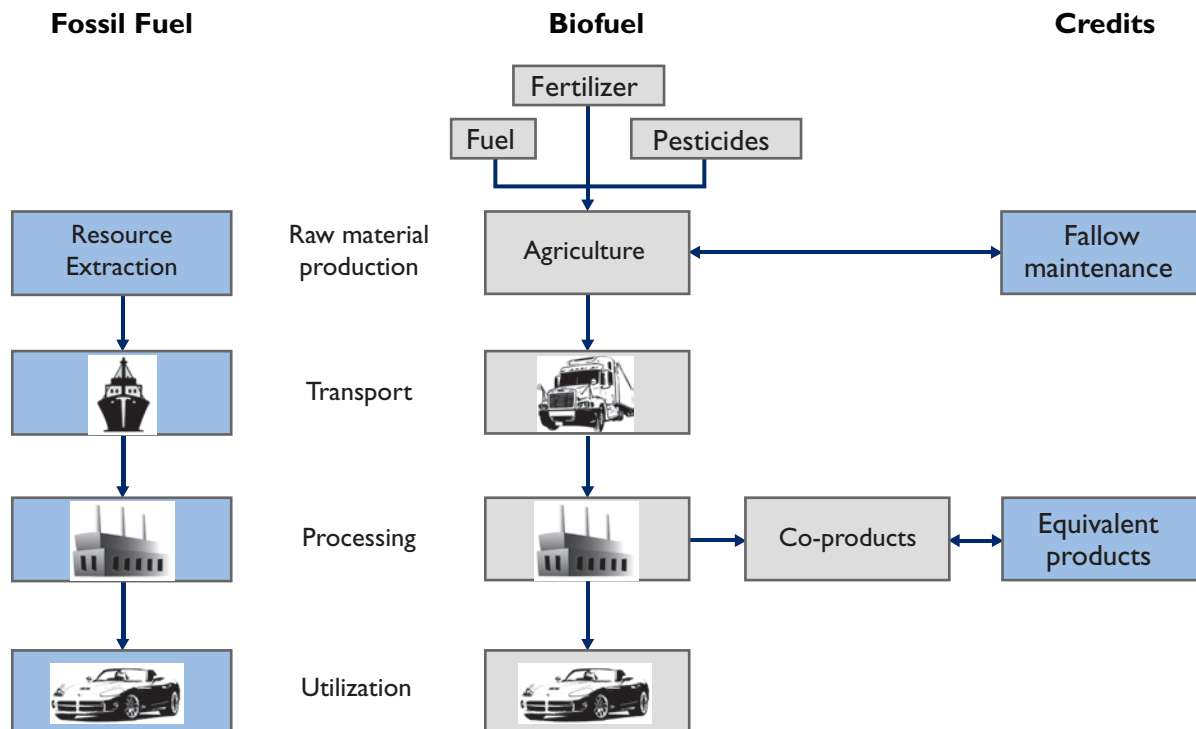
best- and worst-case scenarios are presented in **Annex 3**. It is important to note that the analysis presented here is based on a certain set of parameters and assumptions, and therefore may differ from other LCA results.

NET ENERGY BALANCES FOR VARIOUS FEEDSTOCKS

Net energy is the balance between energy consumed in production and final energy available in the fuel. A fossil fuel system consumes 1.2 MJ of energy per 1.0 MJ of final available energy (as gasoline or diesel). Biofuels feedstock production systems with a net energy balance below 1.2 MJ can be considered to offer an advantage over fossil fuels. Net energy balances over 1.2 MJ mean the biofuels production process consumes more energy than the fossil fuel production process.

Figure 9 shows ranges for net energy balance for production of ethanol from sugarcane, corn, sweet sorghum, and cellulosic feedstocks under best- and worst-case scenarios (with better conditions moving left from 1.2 MJ). The energy balance of sugarcane is most favorable under good operating conditions. Corn is least

FIGURE 8. System Boundary for the Development of the LCA



Source: IFEU, 2008

favorable, with a moderately good energy balance in the best-case scenario, but an energy balance equal to gasoline in the worst-case scenario. Sweet sorghum and cellulosic feedstocks also provide net benefits over fossil fuels.

Figure 10 presents net energy values for biodiesel from oil palm, jatropha, and coconut. All selected feedstocks present

a favorable energy balance in both the best- and worst-case scenarios (again, with better conditions towards the left). Jatropha has the most favorable energy balance under best-case conditions. Palm has the most favorable energy balance in worst-case conditions primarily because of the narrow difference between the best and worst operating conditions. Coconut is favorable in both cases.

FIGURE 9. Range of Net Energy Balances for Ethanol Systems

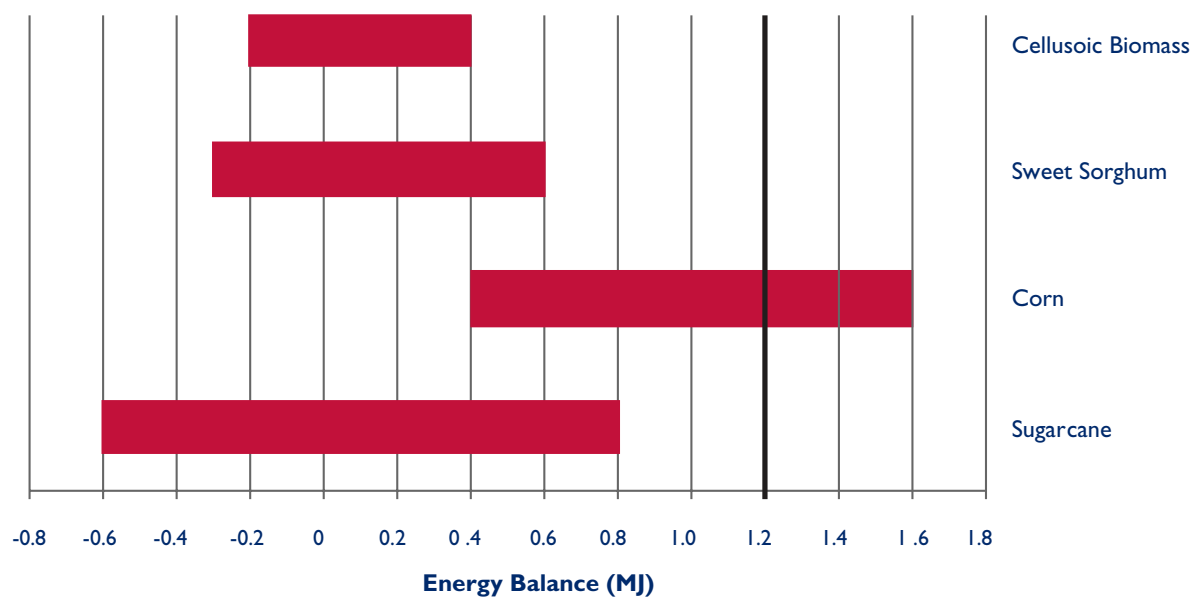
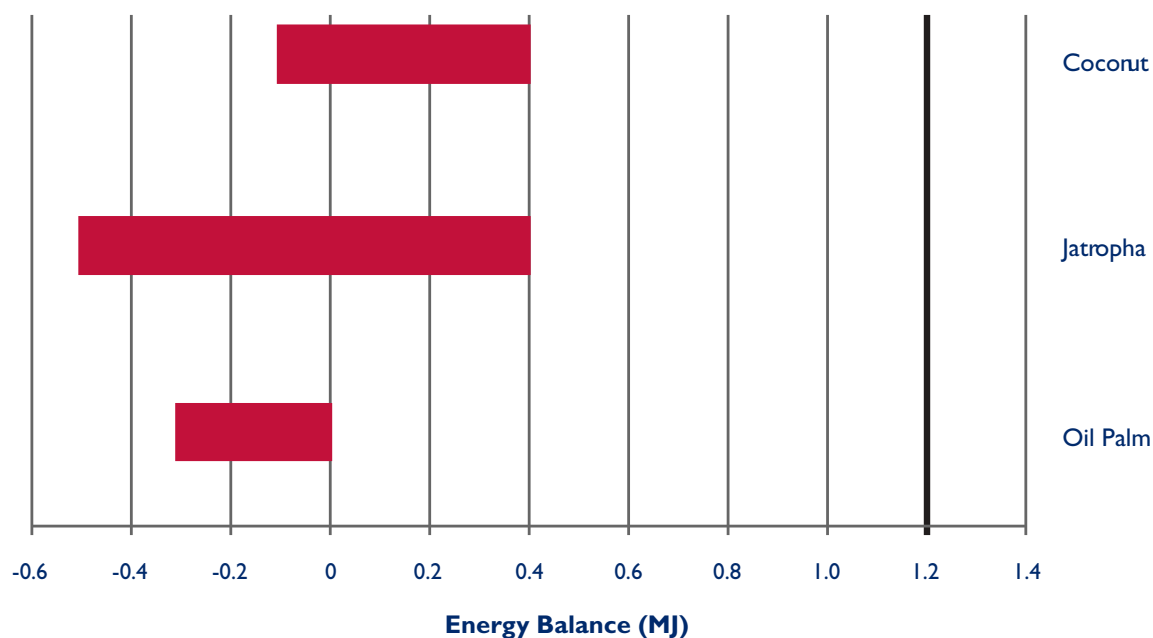


FIGURE 10. Range of Net Energy Balances for Biodiesel Systems



NET GREENHOUSE GAS BALANCES FOR VARIOUS FEEDSTOCKS

Figure 11 shows net GHG emissions from ethanol production processes, accounting for land use change for sugarcane and sweet sorghum, where data were available. Sweet sorghum planted on land with scarce vegetation and sugarcane on existing croplands produces the greatest GHG savings. Interestingly, sugarcane produces similar GHG savings with or without land conversion (based on Brazilian data). In Thailand, large variation in GHG savings is due to disparities in process efficiencies and the lack of use of co-products and wastes.²

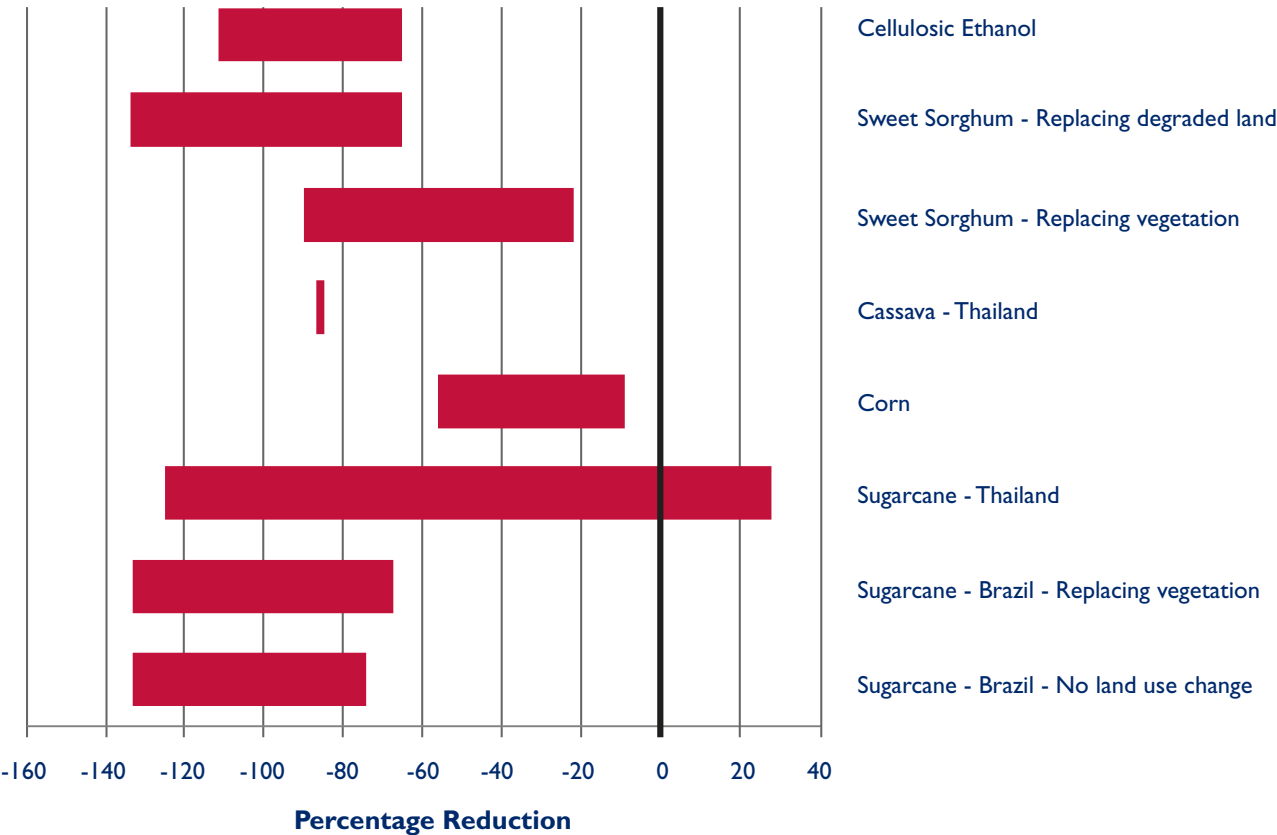
Cellulosic ethanol shows strong GHG savings, but it is outperformed by Brazilian sugarcane. The data for cellulosic ethanol is based on feedstocks grown in temperate regions. It is expected that appropriate cellulosic feedstocks grown in tropical and sub-tropical Asia will have higher yields and will therefore deliver better GHG savings. Data on cassava are limited to one set of conditions in Thailand but

show GHG savings in the middle range. Overall, of all the feedstocks evaluated, corn has the lowest GHG savings.

Figure 12 shows GHG balances for biodiesel feedstocks, taking into account land use change where data are available. When planted on degraded land without loss of natural vegetation, jatropha and oil palm provide the most significant GHG savings. Even though palm oil has the highest GHG savings when planted on degraded or fallow land, in practice palm oil is seldom planted in these areas. When forests or peat, brush, and shrub lands are converted, GHG balances for all feedstocks become highly unfavorable compared to fossil fuels.

CONCLUSION
Results of the LCA suggest that sugarcane, sweet sorghum, and cellulosic feedstocks for ethanol production and jatropha and oil palm for biodiesel production offer the greatest benefits in terms of net energy and GHG savings under the best-case scenario. Under the worst-case

FIGURE 11. Range of Net GHG Balances for Ethanol Systems



² Some Asian processors use coal to generate process energy and steam, which increases overall GHG emissions. In contrast, Brazil has developed a very efficient production chain that utilizes high-yielding energy cane, mechanized harvesting, and bagasse for process energy and ethanol to transport raw materials and the finished product.

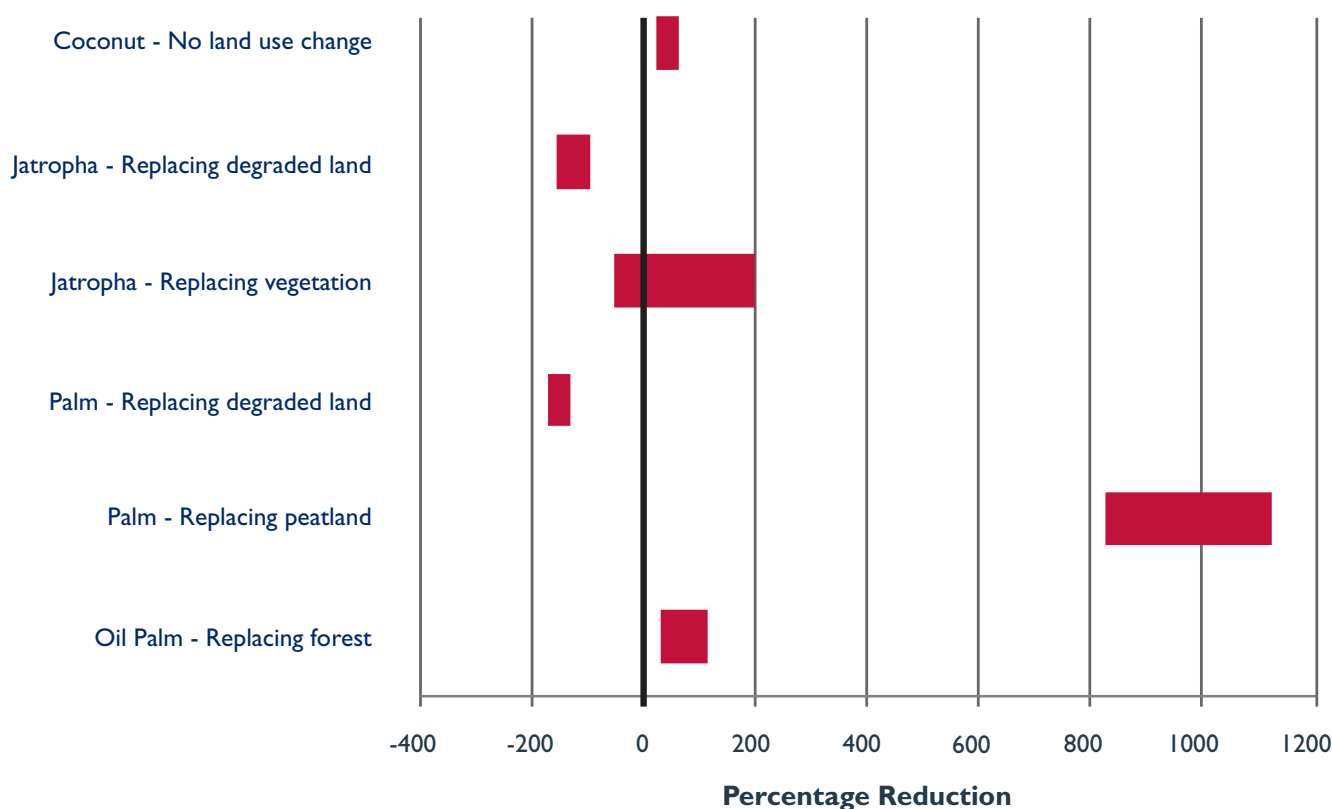
scenario, oil palm can lead to the most significant increase in GHG emissions despite a favorable energy balance. Other feedstocks, notably corn, can present unfavorable energy and GHG balances when produced under poor conditions. Therefore, to ensure biofuels production does not result in worse impacts than fossil fuels, land use changes must be avoided, especially the conversion of peatlands, and process efficiency and co-product utilization must be optimized. The implication is that Asian countries will need to carefully consider the state of the land classified as “available” and take steps to ensure best practices are followed in production.

6.1.2 CARBON DEBT AND BIOFUELS

Biofuels and their land-use change-related carbon emissions can be evaluated by estimating carbon debt and payback periods. Biofuel carbon debt is the amount of CO₂ released from soil and vegetation during the period of time after an area is converted to biofuels crop production (Fargione et al., 2008). Over time, biofuels from converted land can

repay this carbon debt if their production and combustion has net GHG emissions that are less than the life cycle emissions of the fossil fuels they displace. Carbon payback time is the amount of time needed to repay the carbon debt of the biofuels through production and utilization. In general, the carbon debt is highest when low-yielding biofuels crops displace carbon-rich land, such as primary and secondary forests, and peatlands. The carbon debt is lowest when high-yielding crops replace carbon-poor land, such as degraded agricultural lands. High-yielding biofuels feedstocks planted on cropland, degraded or abandoned lands, and in some cases, grasslands, have acceptable carbon payback times of about one year. Second generation, cellulosic fuels are expected to have much smaller carbon debts. However, feedstocks planted on primary or secondary forest, woody savannah, or peatlands result in longer payback periods, up to 1,000–10,000 years. There is no foreseeable technology that justifies the conversion of forest or peatlands for biofuels from a GHG balance perspective.

FIGURE 12. Range of Net GHG Balances for Biodiesel Systems



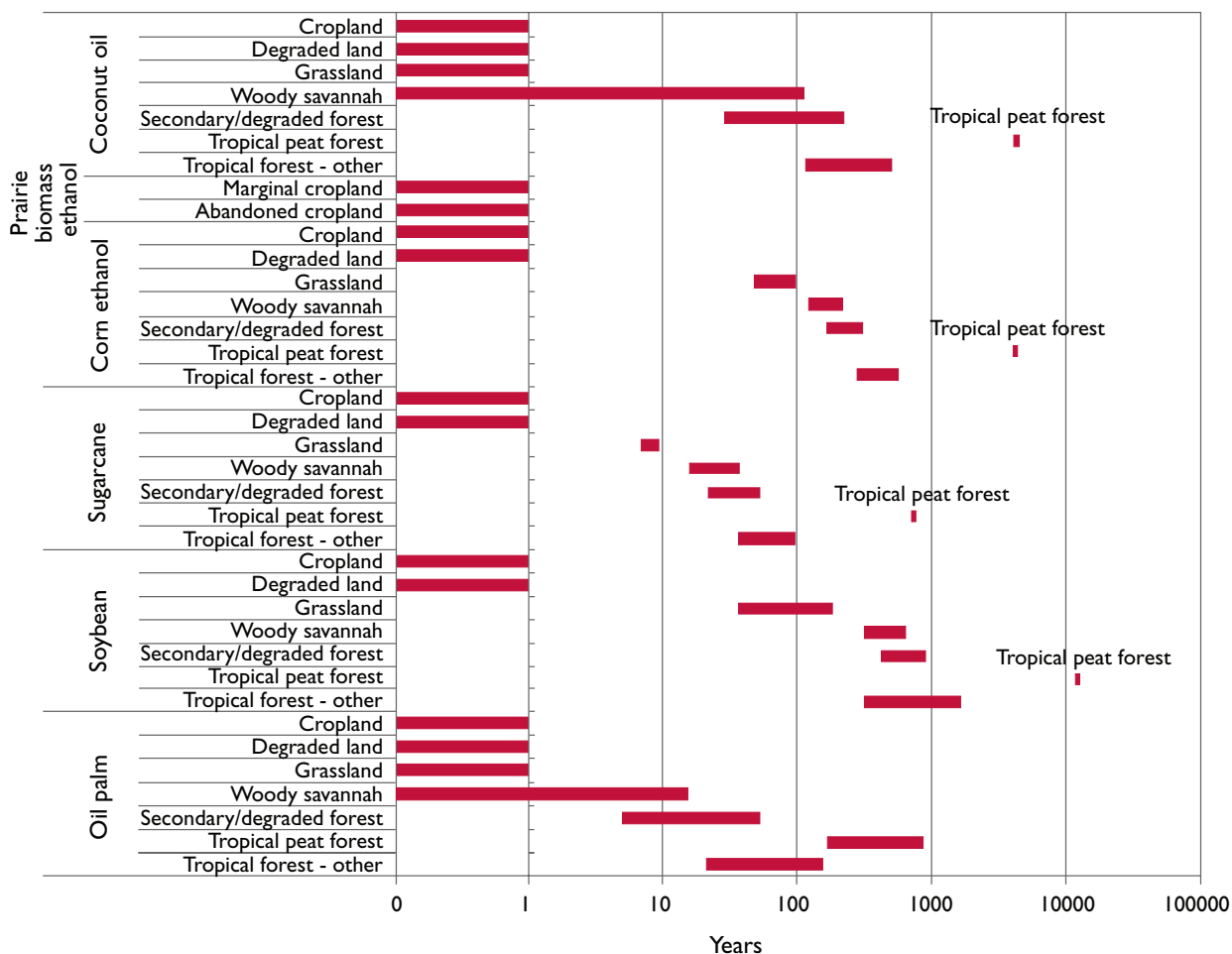
CARBON PAYBACK PERIODS FOR VARIOUS FEEDSTOCKS

Figure 13 depicts payback times for different biofuels crops and within a crop, across various baseline land use types. Debts and payback times vary greatly across biofuels and growth locales, as well as due to the variations in study sites and differences in estimation approaches. Annex 4 provides detailed estimates on carbon debts and payback periods from a variety of studies for biofuels grown in Southeast Asia.

Biofuels feedstocks grown on cropland and degraded land consistently have payback times of one year or less (oil palm may extend to ten years under certain conditions). Coconut and oil palm grown on grasslands also have payback times of one year or less. However, corn, sugarcane, and soybean result in payback periods of 10 to 100 years when planted on grassland. Biofuels feedstocks grown on woody savannah,

secondary forest, or tropical forest generally have payback times of roughly 10 to 1,000 years. Even worse is when biofuels feedstocks are planted on peatlands, which results in payback times of 1,000 to 10,000 years, or longer. In general, feedstocks that replace native vegetation, especially primary and secondary forests and peatlands, lead to unacceptably high payback periods of decades to many centuries. Biofuels plantations on peatlands are of particular concern, especially since peat forests cover 27.1 million hectares in Southeast Asia (Hooijer et al., 2006). Data on deforestation in Sarawak in Indonesia indicated that around half of forest land cleared from 1999 to June 2006 was located on peatlands, many of which were converted to palm plantations (Hooijer et al., 2006). Land use change and deforestation in Indonesia have recently been identified as so significant that the country now ranks third in total GHG emissions globally. Furthermore, an estimated 27 percent of new concessions for palm oil plantations in Malaysia and

FIGURE 13. Ranges of Carbon Payback Times for Biofuels by Major Land Type



Source: USAID ECO-Asia Clean Development and Climate Program, 2009; compiled from sources provided in Annex 4

Indonesia are on peatlands (Fargione et al., 2008). Indonesia, alone, has over 20 million hectares of peat swamps (see **Figure 14**), yet, in early 2009, Indonesia approved a controversial plan to open up peatlands to palm oil plantations (Satriastanti, 2009). It is unclear whether this regulation will be implemented but environmental groups have condemned the policy and are seeking to block it.

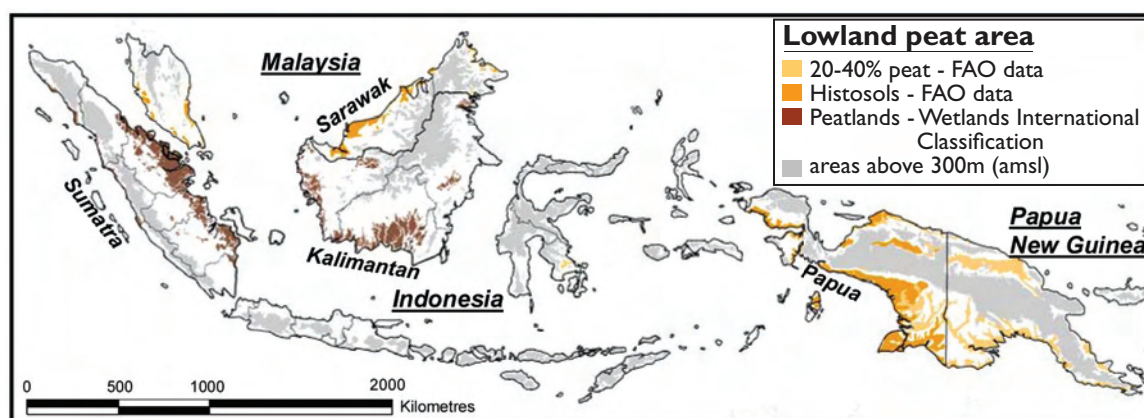
For first-generation crops, biofuels production should minimize the release of carbon stored in soils and vegetation of natural and managed ecosystems to minimize carbon debt and help mitigate climate change. This could be achieved through the production of native perennial fuel crops on degraded and abandoned agricultural lands and use of waste streams (Fargione et al., 2008). Projected future yield increases of biofuels from more efficient cultivars and application of best management practices should also reduce carbon debts and payback times (Fargione et al., 2008; Gibbs et al., 2008). However, payback times will remain long for many pathways, and net GHG emission reductions within a decade or so can only be achieved by the most efficient feedstocks achieving top yields that are grown on degraded or previously cleared lands (Gibbs et al., 2008).

Advanced, second-generation biofuels crops—such as ethanol from switchgrass or prairie and savannah grasses, trees, or forestry waste—are expected to incur much smaller carbon debts (Lynd et al., 2008). Second-generation biofuels plants running on biomass or waste products (e.g., biogas from palm oil mill effluent) would reduce carbon

debt (Wang et al., 2007; Yapp et al., 2008). Even with these advancements, no foreseeable technology will make tropical deforestation for biofuels carbon-beneficial (Gibbs et al., 2008).

There are additional points to consider while evaluating the above estimates. First, biofuels also can increase GHGs indirectly by displacing agricultural production onto other lands (Fargione et al., 2008; Gibbs et al., 2008; Searchinger et al., 2008). In other words, when biofuels expand on arable agricultural land, this may displace food cultivation to new lands, which, when converted, release soil and plant carbon. Many analyses do not account for this effect, thus underestimating carbon debts. Likewise, if land cleared for biofuels production were accruing carbon, then carbon debts through conversion to biofuels production increase compared to those reported in the literature, which are based on the assumption that the displaced natural ecosystems were in steady-state (Fargione et al., 2008). On the other hand, some analyses do not distinguish between biofuels carbon debt proper and co-product carbon debt when estimating carbon debt and payback times. Other uncertainties and research gaps constrain the results from existing studies. These results analyze the CO₂ balance of biofuels only, yet agricultural production causes emissions of other GHGs, such as methane (CH₄) and nitrous oxide (N₂O), which have significantly higher global warming potentials than CO₂. Emission of these gases reduces GHG performance of biofuels, in some cases changing the net GHG effect (Crutzen et al., 2008).

FIGURE 14. Lowland peat areas in Indonesia, Malaysia, and Papua New Guinea



Source: Hooijer et al. (2006)

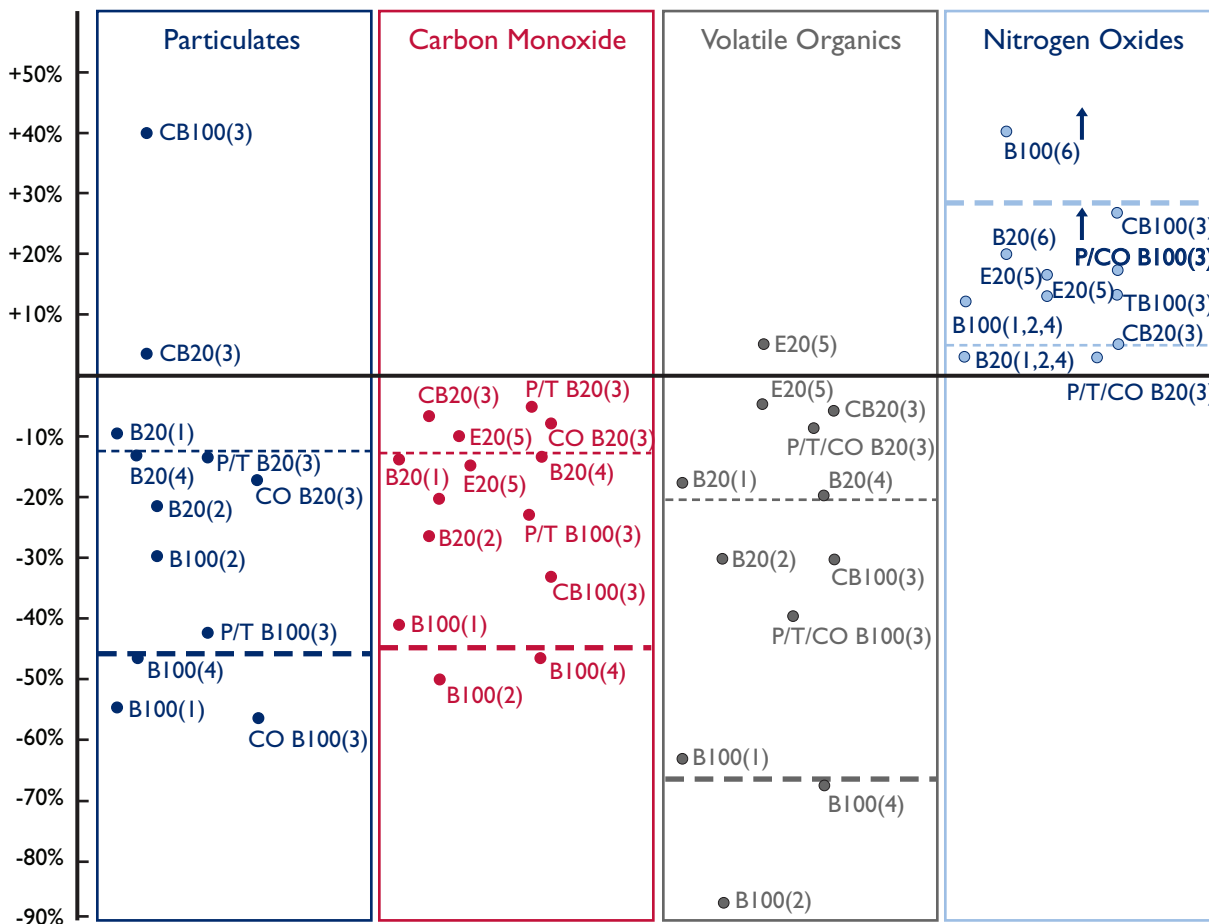
CONCLUSION

The GHG impacts caused during agricultural cultivation of biofuels dwarf those impacts associated with production and transport. The overall GHG impacts of biofuels predominantly results from the clearing of vegetation and the disturbance of carbon-rich soils, such as peatlands. A review of the literature suggests that the production of first-generation biofuels on degraded lands and grasslands are the only definitive options that result in GHG benefits. Some studies contend that in most cases, if net sequestration of atmospheric carbon by plants is the goal, avoiding deforestation and restoring forests on degraded and arable lands generally is preferable to biofuels production (Righelato and Spracklen, 2007; Spracklen et al., 2008).

6.1.3 BIOFUELS AND AIR QUALITY

Poor outdoor air quality is a critical public health concern in many urban areas in Asia (ADB, 2006; Cohen et al., 2005). Health risks associated with sulfur oxides (SO_x), nitrogen oxides (NO_x), and ozone (O_3) are significant in many Asian cities (Wong et al., 2008). However, PM10 concentrations (and PM2.5 to a lower extent) in most cities exceed World Health Organization (WHO) guidelines (WHO, 2006) more than for these other pollutants, making them an issue of particular concern. In most urban areas, road transport—among the fastest growing energy use sectors in much of Asia—is the main source of combustion-based PM10 and emissions (Krzyzanowski et al., 2005; Simachaya, 2008). In this context, this raises the question as to what

FIGURE 15. Estimated Pollutant Emission Changes for Various Biofuels Blends



Sources in parenthesis: (1) NREL, 2003; EPA, 2002; (2) PCI, India, 2003; EPA, 2002; (3) Beer et al., ** 2007; (4) National Biodiesel Board, 2009 (5) PCD, Thailand, 2008; (6) Verbeek, et al., 2008. Compiled by USAID ECO-Asia Clean Development and Climate Program, 2009.

Notes: B20 is diesel with 20% biodiesel; B100 is 100% biodiesel; E20 is gasoline with 20% ethanol; CB= canola-based biodiesel; P BD = Palm oil-based biodiesel; T BD = Tallow-based biodiesel; CO BD = cooking oil-based biodiesel.

The summary represents averages from various studies; the thin dotted line represents B20 averages and the thick dotted line, B100.

** Results indicate performance relative to ultralow sulfur diesel in heavy-duty trucks in Australia.

effects biofuels have on overall air quality impacts from transportation.

Biofuels affect local air quality in two ways: (1) combustion of biofuels and tail-pipe emissions may alter the atmospheric concentrations of local air pollutants and (2) feedstock production may generate emissions as a result of land conversion. On balance, the use of biofuels leads to lower volatile organic chemicals (VOCs), sulfur, and carbon monoxide (CO), but raises NO_x emissions and ozone, and in some cases particulates. Biofuels can contribute to fugitive emissions as well from land-clearing and from untreated processing wastes.

EFFECTS ON TAIL-PIPE EMISSIONS

A number of laboratory and on-road tests have examined the emission characteristics of various biofuels.

Figure 15 presents results of studies of emissions from biofuels compared to gasoline and diesel. In general, biofuels appear to cause lower primary PM₁₀ emissions than fossil fuels, with the notable exception of rape seed-based biodiesel or blends. Use of biofuels in general results in a 60 percent reduction in VOC emissions, thus reducing VOC-based secondary particulate pollution. Experience from Thailand suggests, however, that when used in motorcycles, biofuels may result in marginally higher VOC emissions (PCD, 2008). A switch from regular fuel to biodiesel would reduce sulfur emissions by 20 percent for a B20 blend and 100 percent for B100. Significantly lower carbon monoxide emissions are also expected from most feedstocks.

Of potential concern is that biofuels (especially biodiesel) have higher NO_x emissions than fossil fuels—by as much as 70 percent—depending on the feedstock. NO_x emissions combined with VOCs and other pollutants play a critical role in ozone formation (NARSTO, 2000). Increased NO_x emissions also may raise tropospheric ozone levels, especially along major transport corridors, with negative impacts on health and agriculture locally and regionally (Mauzerall, 2008). Ozone is not considered a

criteria pollutant in many parts of Asia—unlike in North America and Europe—and is not measured regularly.

Nevertheless, ozone concentrations pose significant health risks (Wong et al., 2008). Because of growth in the transport, energy, and industrial sectors, ozone concentrations are critical in evaluating biofuels options (see **Box 4**). In general, highly motorized cities like Seoul, Tokyo, Singapore, and many cities in China and India have lower VOC-to-NO_x ratios.³ Thus, a large-scale switch to biofuels in these cities is more likely to result in increased ozone levels due to the reductions in VOC and increases in NO_x emissions. Large-scale introduction of biofuels could also raise concentrations of NO₂-based secondary PM₁₀. The net effect of a switch to biofuels depends on the relative contribution of primary and secondary PM (VOC and SO₂- and NO₂-based) to total ambient PM concentrations.

EFFECTS ON FUGITIVE EMISSIONS

In addition to tailpipe emissions, large-scale adoption of biofuels may also contribute to fugitive emissions of air pollutants. Fugitive emissions originate from many sources, including from soil erosion from wind in areas deforested to cultivate feedstock, and from burning vegetation on cleared lands. Fugitive emissions from wind erosion may be substantial, but are not generally of great public health concern. In contrast, emissions from vegetation burning are a greater problem (Jacobson, 2008). For example, frequent vegetation burning, including but not limited to clearing land for biofuels production, causes severe smog across parts of Southeastern Asia, with associated impacts on human morbidity and mortality (Schwela et al., 2006; Bowman and Johnston, 2005).

CONCLUSION

It is difficult to predict the cumulative impact on air quality in Asia from a large-scale switch to biofuels. If land clearing and vegetation burning were largely avoided, the impacts would primarily result from the differences in tailpipe pollutant emissions between biofuels and fossil fuels. On balance, a switch from fossil fuels to biofuels may benefit

3 The formation of ozone depends on the extent of sunlight that is present and the relative ambient concentrations of VOCs or NO_x. In urban environments, the photochemical reaction sequence initiated by NO_x, VOCs, and CO can cause ozone pollution levels to increase or decrease depending on the relative concentrations of these chemicals. Jacobson (2007) suggested that substitution of gasoline or diesel with E85 (an 85-percent ethanol mix) in the United States would lead to increased ozone formation by 2020 (Box 4). However, given the complex photochemistry involved in ozone formation, the increase in NO_x emissions, and the reduction in VOCs emissions expected from large-scale displacement of fossil fuels by biofuels, the net effect of biofuels on tropospheric ozone levels is difficult to predict in Asia. VOC:NO_x emission ratios (mass based) in Southeast Asia vary widely, ranging from around 10:1 in Jakarta to less than 1:1 in Seoul (Guttikunda et al., 2005).

Box 4. Air Quality Impacts of Biofuels vs. Other Clean Energy Technologies

Jacobson (2008) conducted an in-depth evaluation of 12 combinations of renewable and nuclear electric power and fuel sources, and analyzed their ability to address climate, air pollution, and energy problems simultaneously in the United States. His analysis considered nine electric power sources, two liquid biofuels (corn and cellulosic ethanol), and three vehicle technologies.

A large-scale switch from reformulated gasoline to high ethanol blends in the US would result in increased emission of local air pollutants and associated incidence of health risks (Jacobson, 2007). In contrast, all other renewable electricity-based fuel sources and vehicle technology combinations caused much lower air pollution emissions than the two biofuels. When Jacobson merged results of the individual analyses, the two biofuels had the lowest overall ranking, and thus the least desirable options for addressing the combination of issues analyzed.

These findings are based on the particular context of the United States and not necessarily applicable to other countries. Nevertheless, the analysis provides an instructive example of the range of issues that need to be included in a comprehensive evaluation of clean energy options.

local air quality in Asia, with the caveats outlined above. Further, from the perspective of longer-term energy and air quality planning, it is important to evaluate air quality benefits from other cleaner transportation options—namely generating electricity from biomass and other alternate means (e.g., wind) for plug-in electric vehicles. Alternative energy sources may fare better than biofuels with respect to air quality. The feasibility of large-scale deployment of these alternatives in Asia deserves examination before drawing conclusions about the desirability of biofuels from an air quality perspective.

6.1.4 BIOFUELS PRODUCTION AND BIODIVERSITY

One of the most significant issues associated with biofuels development in Asia is the impact on the region's biodiversity,⁴ which is considered to be among the greatest worldwide. For example, it has been estimated that the island of Borneo alone has more than 15,000 known species of plants; some areas of its primary forest may have as many as 240 species of tree in a single two-hectare site (White, 2008). Altogether, Indonesia and Malaysia have around 6,500 and 1,500 known animal species, respectively (IATP, 2008).

There are several drivers that cause the continuing destruction of tropical forests in Asia, including population

growth, poverty, demand for timber, and poor institutional capacity to monitor and enforce rules in protected areas. The increased demand for biofuels in many cases has served as an additional driver. As discussed earlier in this report, many biofuels crops are ideally suited to tropical areas and this creates significant economic incentives to convert forests to support biofuels production. In addition, biofuels can negatively affect biodiversity by promoting mono-cropping, which relies on a narrow pool of genetic material, and leads to a reduction in agricultural biodiversity. On the other hand, it can be argued that biofuels production, under certain conditions, and when used to restore degraded lands, may also actually contribute positively to biodiversity.

BIOFUELS-RELATED DRIVERS OF FOREST LOSS

Over the past two decades, considerable forest land in tropical Asia has been cleared to make way for plantations. This is especially the case with oil palm plantations. Worldwide, land under palm cultivation has increased from about 4 million hectares in 1980 to 14 million hectares in 2008, mostly in Indonesia and Malaysia. It has been estimated that slightly more than half of the oil palm expansion in Malaysia and Indonesia—or about 7 million hectares—occurred at the expense of forests (Koh and Wilcove, 2008). While both Malaysia and Indonesia have stated that new palm oil plantations will

⁴ For the purposes of this report, biodiversity is defined as the sum total of plant and animal life that is resident in a particular location. It is often used as a measure of the health of biological systems, as habitats that are richer in species are usually more stable and resilient to outside influences. A high level of genetic diversity is a crucial factor in enabling species to adapt to changing environmental conditions and thus to evolve further.

not result in forest conversion, the drive for large-scale agro-industrial projects will continue to threaten forests in both countries.

In Malaysia, a majority of new oil palm developments are in the states of Sarawak and Sabah. These state governments have a great deal of autonomy and environmental impact assessments are not always performed (GSI, 2008c). Many Malaysian companies also operate in the Indonesian provinces of Kalimantan and Riau, which have high rates of forest conversion for oil palm and less rigorous government oversight.

Biofuels can also lead to forest loss indirectly. For example, in Indonesia, it has been reported that plantation companies are allotted land to establish oil palm plantations; however, quite often it is their sister companies—which

focus on timber and pulp operations within the same industrial conglomerate—which extract the high-value timber and then abandon the land, without the subsequent establishment of oil palm plantations (**Box 5**). The use of fires for clearing forest land designated for plantation development also leads to additional forest loss. Slashing and burning is cheaper and quicker for plantation companies than any other method of clearing. These fires often spread to nearby forests, causing significant damage. When fires were burning completely out of control at the end of 1997 and various bans on the use of fire were imposed by the Indonesian authorities, fire hot spots were still observed by satellites in areas designated for future palm oil plantations. It is estimated that about 5.2 million hectares of land were damaged by fires in the Indonesian province of East Kalimantan, Borneo alone during the 1997/98 El Niño season (Cleary et al., 2004).

Box 5. The Kalimantan Border Oil Palm Mega-Project

In mid 2005, the Indonesian government announced plans to develop what would be the world's largest oil palm plantation in a 5-10 kilometer zone along the border of Kalimantan and Malaysia. The US\$567 million investment was to come from a variety of sources including Indonesian companies and Chinese investors.

Independent analyses of the business plan developed by the Indonesian State Plantation Corporation (PTPN) suggested that the 1.8 million hectare project would severely deforest land in three National Parks. The Kalimantan border zone forms a major chunk of a 22 million hectares area in Sarawak, Sabah, Brunei, and Kalimantan that WWF labeled the “Heart of Borneo” (HoB). HoB has been conceptualized as a conservation approach that includes better management of existing protected areas, wildlife corridors, expanding protected areas, and sustainable forest use. According to the WWF, the HoB area is one of the richest globally in terms of biodiversity.

An issue of particular concern was that much of the land in question has been deemed to be unsuitable for oil palm cultivation, raising the likelihood that project promoters were more motivated by the lure of cashing in on the high-value timber in this area rather than establishing oil palm plantations. Ironically, this project was announced a few years after the abandonment of the 1 million hectares Mega Rice Project in Central Kalimantan, which did not lead to any significant rice cultivation but caused unprecedented loss of forest area, peatlands, and wildlife.

Wide-ranging campaigns and criticism from civil society, the media, and international actors forced the Indonesian government to revise its plans for the project. The government pledged to exclude protected areas and areas not suitable for oil palm, and support the HoB conservation initiative led by WWF. The government has revised its plans and reduced the total acreage of 150,000 hectares.

Source: AIDEnvironment, April 2006

BIODIVERSITY IMPACTS OF LAND USE CHANGE

Several studies published recently have concluded beyond doubt that palm plantations are impoverished in flora and fauna biodiversity relative to the original forest tracts (IATP, 2008; WWF, 2007b). Danielsen et al. (2008) found that species richness of birds, lizards, and mammals was much lower in oil palm plantations. Only 23 percent of the vertebrate species and, with some exceptions, only 31 percent of invertebrate species found in tropical forest were present in plantations. The study also showed a lack of other forest vegetation such as lianas, orchids, and indigenous palms in the plantations. Deforestation on the scale that has been reported in Indonesia in recent years—around 2 million hectares annually—will also increasingly lead to reduced and more fragmented habitat for local species, and further contribute to biodiversity loss.

Loss of natural habitats through land conversion for biofuels production has been well documented in other countries outside Asia. For example, agriculture expansion is causing land conversion and resultant habitat loss in Brazil (**Box 6**). Similarly, in the US and Europe demand for new acreage has triggered extensive land use changes with negative impacts on biodiversity, including impacts in far-away countries. The ongoing discussion on converting land in conservation reserve programs and “set-aside”⁵ land in the US and Europe, respectively, back into land for annual biofuels feedstock crops could further exacerbate these risks to biodiversity.

ALTERNATIVES TO DEFORESTATION

On the other hand, if wastelands or degraded lands are converted to biofuels plantations, the biodiversity on the site can be enhanced. There are several examples from around the world where such conversion of degraded lands or abandoned agricultural lands have led to increased plant life and overall biodiversity. For example, the introduction of perennial grasses such as switch grass or trees like willows can improve regional biodiversity relative to the on which they are established (Volk et al., 2004). Expanding native prairie next to farmlands sustains a diversified range of pollinators, thus helping crops (Groom et al., 2007).

There is significant potential for a substantial area of degraded land to benefit from biofuels plantations in Southeast Asia. After natural tropical forest has been logged

and cleared, often by fire, and perhaps cultivated for a brief period of time, the affected area develops into a wasteland, often overgrown with alang-alang grass which prevents the land from developing naturally into secondary forest. According to a study by Otsamo (2001), there are between 8.6 and 64.5 million hectares of alang-alang grasslands in Indonesia alone. Dros (2003) has published a more conservative estimate of about 10 million hectares. It is unclear if any of this land is suitable for oil palm cultivation. It is more likely that the land is better suited to cellulosic ethanol feedstocks that tend to be hardier and grow on drier habitats. Nevertheless, this degraded land represents an enormous potential and could considerably reduce the pressure on natural forests.

Another option to take pressure of the natural forests is to convert existing plantations into biofuels plantations. This has happened for example in Malaysia, where many rubber, cocoa and coconut plantations in that country have been converted into oil palm plantations.

BIODIVERSITY IMPACT OF MONOCULTURES

Biofuel production may also have a significant impact on the biodiversity of agriculture itself. In traditional agriculture-based biofuels production, economies of scale requirements inevitably encourage monoculture—the agricultural practice of growing a single crop over a large area. Monoculture is harmful to the biodiversity of a region primarily because widespread planting of a single crop functions as an incubation medium for pests or disease, which can devastate the crop and spread into natural habitats (Karthi, 2006).

At the same time, innovations in agriculture are demonstrating that polyculture systems may provide multiple benefits and can be pursued without sacrificing biomass productivity. In well-designed polycultures, different crops cultivated side-by-side (intercropping) or in rotation support agricultural biodiversity and reduce the use of pesticides and synthetic fertilizers. Large-scale polyculture has been achieved in a number of contexts, including rice and fish farming in China, and cattle and grain rotation in Argentina (Pollan, 2008). Intercropping of compatible plants encourages biodiversity by providing a habitat for a variety of insects and soil organisms that would not be present in a single-crop environment.

⁵ Annual cropping is currently not allowed on these lands owing to their vulnerability to erosion and potential impacts on water quality. Farmers receive an annual payment for maintaining perennial vegetation cover on these lands.

It has been proposed that these developments can be applied easily to biofuels production. Ongoing research on the development of feedstock production systems using perennial grasses and woody species, such as willow, is predicated on the use of polycultures-based systems involving different varieties and species (Volk et al., 2004). Data from a multi-year experiment established on degraded and abandoned soils suggests that high-diversity mixtures of native grassland perennials are able to produce higher amounts of biomass, relative to maize-ethanol or soybean diesel, and that performance improved with the number of species included (Tilman et al., 2006).

CONCLUSION

If managed imprudently, future expansion of biofuels production will lead to further loss of tropical forests, and the expansion of the agricultural frontier. Evidence shows biofuels plantations support significantly lower amounts of biodiversity, relative to native forests and productive grasslands.

A fundamental component in developing sustainable biofuels feedstock cultivation must be protection of natural

landscapes. However, preservation of high-conservation value areas is unlikely without monetary incentives greater than the promise of profits from logging or oil palm. Growing highly productive biofuels feedstocks on degraded land could benefit biodiversity. To the extent possible, plantations should deploy polycultures, which support biodiversity while also allowing for higher productivity.

6.1.5 IMPACTS OF BIOFUELS PRODUCTION ON WATER RESOURCES

Large-scale biofuels production consumes water and impacts water quality in a variety of ways. These impacts include: (1) use of water to grow and process feedstock into fuels; (2) release of agrichemicals into surface and ground water; and (3) change in local watershed hydrology caused by the biofuels crop. Moderate to high water withdrawal rates—particularly in China, India, and Vietnam—in addition to predicted water shortages due to climate change, mean that water supplies are already threatened in developing Asia. Ambitious plans to scale up biofuels production will only increase water demands. Biofuels feedstocks, such as sugarcane and oil palm, have high water demand and thus should only be considered in

Box 6 Biodiversity Loss in Brazil

The heart of Brazil's ethanol production is the south-central Atlantic Rain Forest region (Mata Atlantica). Rated one of the top biodiversity hotspots in the world, it contains some 20,000 plant species and is home to numerous endangered mammals, including the marmoset and the golden lion tamarin. The Mata Atlantica is also one of the most intensely farmed areas in the country, home to more than 60 percent of Brazil's sugarcane cultivation and 85 percent of its ethanol output. Although the Mata Atlantica once covered more than 100 million hectares, today only about 7 percent remains, much of it severely fragmented.

Expansion of sugarcane monoculture has also placed increasing pressure on the Cerrado biome in Brazil's central highlands. It is the world's most biodiverse savannah, home to an estimated 10,000 species of plants (4,400 of which are endemic), 607 birds, 225 reptiles, 186 amphibians, 800 fresh water species, and 195 species of mammals, including unique inhabitants like the marsh and pampas deer, giant anteater, maned wolf, and giant armadillo (Biofuelwatch et al., 2007).

The Cerrado has been extensively developed for soybean production as well as the production of corn, cotton, coffee, and cattle. An estimated nearly 60 percent of the Cerrado's original vegetation has been completely destroyed, and it continues to be cleared at a rate of around one percent every year (Butler, 2007). Only 2.2 percent is legally protected. Conservation International predicts the Cerrado could disappear by 2030 (IATP, 2008).

While demand for beef and soybean fueled the clearing of the Cerrado in the past, demand for sugarcane and soybeans for biofuels will likely accelerate the future loss of biodiversity. Moreover, expansion of sugarcane in other areas may displace other crops, including soybean, pushing more cultivation into the Cerrado and possibly into the Amazon, which represents more than half of the world's remaining rainforest.

areas that receive sufficient rainfall. Other crops, such as jatropha and sweet sorghum, have much lower water requirements in combination with a good ratio of biofuels yield per unit of water. Additionally, biofuels have the potential to contribute to water pollution problems—through fertilizer runoff and discharge of untreated processing wastes into nearby water bodies.

AVAILABILITY AND COMPETITION FOR WATER RESOURCES

Agriculture in Asia consumes more water than all other regions of the world combined. Water utilization and consumption are shown in **Table 16**. A commonly used indicator of water stress is the ratio of water withdrawals to total renewable water. India, Vietnam, and China have the highest withdrawal rates. Even in countries where withdrawal rates are relatively low (e.g., some parts of Southeast Asia), economic factors may occasionally result in local scarcity.

In the next decade, projected population increases of more than 500 million and higher levels of affluence in the Asia region will increase water withdrawals for agricultural, industrial, and domestic uses (ADB, 2007). Water scarcity is expected to worsen, particularly in India, where withdrawal rates are expected to exceed 40 percent. Climate change-induced effects may exacerbate these trends. South and Southeast Asia in particular may experience water stress (Cruz et al., 2007).⁶ These changes are expected to lower overall agricultural productivity.⁷

Overall, Asia's rice production may decrease by 3.8 percent by the end of this century. In some areas, crop yields may drop by as much as 2.5–10 percent by 2020 and 5–30 percent by 2050. Decreased productivity of rain-fed agriculture would increase irrigation-related water demand, creating a vicious cycle that further increases freshwater withdrawals.

WATER REQUIREMENTS TO PRODUCE BIOFUELS

Biofuels production consumes water in three ways: (1) evapotranspiration⁸ (ET) during crop growth; (2) evaporation in the biomass during the pre- and post-harvest drying process and feedstock pre-treatment; and (3) processing of biomass into biofuels. This section focuses on ET and its determining factors because globally, ET uses at least 50 times more water than the other two activities (Berndes, 2008).

ET depends on the interplay of factors related to climatic conditions (e.g., solar radiation, temperature, wind velocity), crop characteristics (e.g., growth stage, leaf area), soil characteristics (e.g., porosity, moisture content), and water availability. It varies by region, time of year, and crop. It can be evaluated in terms of amount of the water required per year for a growing period for the crop, or in terms of water required to produce a unit amount of the feedstock or biofuels (**Table 17**). Among Asian feedstocks, sweet sorghum and sugarcane have the highest yield per unit of water consumed—3.45 kilogram per millimeter (kg/mm) and 1.65 kg/mm, respectively. Corn has the lowest yield per unit water consumed. On the demand side, coconut, jatropha, and oil palm have the highest yields—5.20 kg/mm, 2.67 kg/mm, and 2.33 kg/mm, respectively. Soybean has the lowest yield among the biodiesel feedstocks.⁹

In order to understand the water demand-related impacts of biofuels, it is instructive to evaluate the total amount of water withdrawn at current levels of production. Fraiture et al. (2008) estimates that global biofuels production in 2005, carried out on 11–12 million hectares, used about 1 percent of total cropland, about 1 percent of total crop ET demand, and about 2 percent of global irrigation water (**Table 18**). The share of irrigation water is slightly higher because of the relatively large share of irrigated sugarcane in the biofuels mix. On average, it takes 2,500 liters of crop ET and 820 liters of irrigation water to produce one liter of biofuel, albeit with large regional variations depending on whether the crop is irrigated or rain-fed. Biofuels currently

6 It is predicted that in Northern China, in the near term, only 70 percent of the agriculture water demand will be available. Water availability in India is estimated to reach below 1000 m³/year by 2025.

7 Some regions may instead see an increase in productivity. East Asia may increase crop yield by 20 percent.

8 Evapotranspiration (ET) is a sum of evaporation and plant transpiration. Evaporation is movement of water into air from soil, water bodies, and canopy interception; and transpiration is the loss of water through the stomata in the leaves. The ET rate is the amount of water (usually in mm) lost due to ET over a unit time period.

9 Sugarcane and maize require substantial liters of irrigation water per liter of ethanol produced. Brazilian sugarcane requires 90 liters of water per liter of ethanol, Indian sugarcane uses 3,500 liters of water; US maize (rain-fed) uses 400 liters compared to Chinese partly irrigated maize, which required 2,400 liters of water (IVMIL, 2008).

Table 16. Agriculture Water Use in the Focus Countries

	Total renewable water resources (cubic km)	Irrigation water requirements (cubic km)	Water requirement ratio in percentage of renewable water resources	Water with-drawal for agriculture (cubic km)	Water withdrawal as a percentage of renewable water resources
China	2829.6	153.9	3%	426.9	15%
India	1896.7	303.2	5%	558.4	29%
Indonesia	2838	21.5	2%	75.6	3%
Malaysia	891.2	15.2	3%	48.6	5%
Philippines	580	1.7	3%	5.6	1%
Thailand	479	6.3	3%	21.1	4%
Vietnam	409.9	24.8	3%	82.8	20%

Source: 2000 FAO AQUASTAT

Table 17. Water Requirements of Major Energy Crops

CROP	Water required, low to high (mm/year)	Biofuel yield per unit of water (kg/mm)	Growing season/ time to full maturity
Sugarcane	1,500 - 2,500	1.65	10-12 months
Sorghum	450 - 650	0.82	4-5 months
Sweet sorghum	450 - 650	3.45	4-5 months
Oil Palm	1800 - 2,500	2.33	10-12 years (25)
Jatropha	150 - 300	2.67	3-4 years (20)
Coconut oil	600 - 1,200	5.20	5-10 years (50)
Maize/Corn	500 - 800	0.69	4-5 months
Rapeseed	350 - 450	0.83	120-150 days
Sugar beet	550 - 750	11.34	5-6 months
Wheat	450 - 650	1.09	4-5 months
Soybeans	450 - 700	0.35	100-150 days
Sunflower	600 - 750	0.32	100-120 days
Groundnut	400 - 500	1.13	100-120 days

Sources: Rajagopal and Zilberman, 2007; Berndes, 2002

Note: Numbers in parentheses refer to the lifespan of the crop

have a very modest ecological footprint in terms of land and water use, although there may be severe impacts in specific locations.

Aggressive plans to scale up biofuels production require an evaluation of the implications for water use. By 2030, biofuels could account for nearly 8 percent of total transportation fuel demand globally, with wide variations among countries. According to Fraiture et al. (2008), after accounting for increased food production—particularly maize and sugar—to meet demand, the increased demand for biofuels would require an additional 180 million metric tons (MT) of maize (20 percent increase), 525 million MT of sugarcane (25 percent), and 50 million MT of oil crops (80 percent). This additional feedstock will require 30 million additional hectares of cropland (compared to 1400 million hectares for food), 170 km³ additional ET (compared to 7,600 km³ for food), and 180 km³ for irrigation (compared to 2,980 km³ for food). This translates to a 3 percent increase in land area and ET, and a 4 percent increase in irrigation water usage.

Overall, increases in water demands could be supported by the global resource base, but the situations in China and India are particularly constraining. To meet biofuels requirements in 2030, China would need to increase maize production by 25 percent, on top of an estimated 60 percent increase to meet food and feed needs. Due

to water constraints in the north and to land and labor constraints in the south, China is unlikely to be able to produce this amount. To satisfy food demands, imports will likely need to be increased. Producing more maize for biofuels would lead to water degradation and major shifts in cropping patterns.

The challenges are similar in India. India's food supply is very irrigation-dependent. Most rice- and wheat-growing areas and over 85 percent of the sugarcane area are irrigated, with limited scope for expansion. Cereal and vegetable demand is projected to increase by 55 percent and 90 percent, respectively, by 2030. India would need to produce an additional 100 million tons of sugarcane to meet ethanol needs, but producing this additional amount is likely to degrade resources and impact other crops. Non-food crops, such as jatropha and agricultural and woody residues, could lower overall water demand. Jatropha can be established on marginalized lands without irrigation, but current yields are low (1500 liters per hectares) and commercial operations would require irrigation to boost yields to economical levels.

IMPACT OF BIOFUELS ON WATER QUALITY

Water pollution is a serious threat throughout developing Asia. Roughly 655 million people (17.6 percent of the population) in South Asia lack access to safe drinking water (UNEP, 2007). More than 80 percent of the waste in South

Table 18. Biofuels Production and Use of Land and Water Resources, 2005 and 2030

MAIN FEEDSTOCK CROP		Biofuel produced		Feedstock used (million metric tons)		% total cropped area used for biofuel		% of total ET used for biofuel		% of total irrigation withdrawals for biofuels	
		2005 (million liters)	2030 (billion liters)	2005	2030	2005	2030	2005	2030	2005	2030
China	Maize	3649	17.7	9.4	45	1.1	4	1.5	4	2.2	7
India	Sugar cane	1749	9.1	19.4	101	0.2	1	0.5	3	1.2	5
Thailand	Sugar cane	280	NA	3.1	NA	0.3	NA	0.8	NA	1.9	NA
Indonesia	Sugar cane	167	0.8	1.9	9	0.1	0	0.3	1	1.2	7
World		38780	141.2			0.9	3	1.4	3	1.1	4

Source: Fraiture et al. (2008); NA = data not available

Box 7. Biofuels Crops and Hydrological Flows in the Krishna Basin

The Krishna basin in Southern India illustrates the complex linkages between hydropower, groundwater pumping, and lift irrigation systems. Growing irrigated sugarcane for ethanol production could help to meet the growing demand for fuel. However, the water resources of the Krishna basin are fully allocated, and further withdrawal would mean water will not be available to meet all current demand in drier years. Growing more irrigated sugarcane for biofuels would put further stress on the river basin.

Source: McCormick et al. 2008 cited in IWMI, 2008.

and East Asia is untreated and often ends up in aquatic systems (UNEP, 2007). Biofuels can contribute to water quality problems through agrochemicals in feedstock production and generation of effluents during fuel processing. Fertilizers often leave a site and enter surface and groundwater systems, and pesticides can similarly infiltrate groundwater. The impact of fertilizers used for biofuels is discussed in the next section.

Effluent generation and treatment is feedstock-specific. Ethanol production from corn leads to three waste streams: brine byproduct, organic matter-rich wastewater, and wastewater resulting from cleaning up salt build-up in cooling towers and boilers (NRC, 2008). Data from ethanol-producing refineries in Iowa show that the salt content of refineries is three times the salt concentration of regional groundwater (NRC, 2008). Dumping organic matter-rich wastewater into natural waterways without treatment could increase Biological Oxygen Demand (BOD). Sugarcane-based ethanol production produces organic matter, hot water and wastewater flows that contain grease, oil, acid, and sugar that should be filtered and treated before release or reuse (Smeets et al., 2006). Per unit of fuel produced, ethanol from molasses produces more waste than ethanol directly from sugarcane juice. For palm oil production, 50 percent of water used becomes palm oil mill effluent (POME), the largest pollutant of Malaysian rivers. Most of this water can be recovered and recycled (Ahmad et al., 2006), but if discharged untreated, POME dissolves oxygen in water.

CHANGES IN WATERSHED HYDROLOGY

Vegetation, terrain, microclimate, and human activities (such as irrigation) affect water hydrology. Converting land to biofuels production can result in wide-ranging changes

in local and regional hydrology (**Box 7**). For example, converting dense tropical forests to palm plantations lowers vegetation cover and ET, leading to increased groundwater supplies and surface runoff. In contrast, going from degraded agricultural land to tree crops increases overall ET, lowering ground water supplies.

Switching from one crop to another also impacts hydrology if irrigation is used. When groundwater is used for irrigation, it is converted into “green water” (water available in the root zone) and some is lost as runoff. Even rain-fed agriculture changes the hydrology if the replacement energy crop has a higher ET. A higher ET implies a larger fraction of the rainfall is lost, thus reducing groundwater recharge and reducing stream flow. Replacing an existing plantation with a lower ET crop has the reverse effect.

CONCLUSION

The analysis of existing research on biofuels and water use indicates that when averaged across the globe, current biofuels feedstock production accounts for a small percentage of total water (about 1 percent) and irrigation water (about 2 percent) used in agriculture. If production from food-based biofuels were to expand to meet projected 2030 targets, these figures would increase proportionately to about 2-5 percent globally. This expansion will have severe consequences for China and India, given their existing water resource constraints. It is unlikely that China and India could meet future food, feed, and biofuels demand without severely aggravating existing water scarcity problems or importing grain with related food security implications (see **Section 6.3**).

6.1.6 IMPACTS OF FERTILIZER USED IN BIOFUELS PRODUCTION

Increased demand for biofuels could be met by bringing

more land under production or by intensifying production within existing crop-growing areas. Both approaches will likely increase the demand for organic and inorganic fertilizers. Increased fertilizer use aggravates eutrophication through fertilizer run-off, and in some cases may result in a greater dependency on non-renewable, expensive, imported fertilizers.¹⁰ For biofuels feedstock production to be sustainable, fertilizer application must be minimized to the extent possible. While technical options for retaining site fertility and lowering fertilizer demand exist, they are not widely implemented even for food crops. This section reviews biofuels fertilizer application needs and practices and the associated implications for the environment and socio-economic status of farming communities.

FERTILIZER DEMAND OF BIOFUELS CROPS

Fertilizer demand depends on crop type, production and management system, and inherent fertility of the land on which biofuels feedstocks are grown. In general, annual food crops have higher nutrient demands than non-food crops and perennial woody crops. Even among food crops, nutrient demand varies. For example, corn requires more fertilizer than soybeans. **Table 19** compares yields with low fertilizer use (field application rates in developing countries) with optimal levels recommended by agronomic research for key biofuels crops. In all cases, the application of optimal levels of fertilizer significantly increases yields.

Research trials also indicate fertilizer dramatically increases yields for perennials and non-food crops. For example, in switch grass plantations, the doubling of fertilizer (e.g., from 75 pounds to 150 pounds per acre) doubled yields (e.g., from 4 to 8 US tons per acre) (Fixen, 2007). As these biofuels crops are commercialized on larger acreages, there is a strong economic incentive to use fertilizer to maximize yields. However, in general, these crops have low nutrient demands relative to annual food crops.

Crop management systems also influence fertilizer demand. Feedstock production systems for cellulosic ethanol produced from agricultural waste or aboveground biomass have higher fertilizer requirements when residue and stems/leaves are removed, which would have otherwise decomposed and returned nutrients to the soil. Inherent soil fertility also influences fertilizer use.

Most analyses suggest energy crops should be grown on unutilized or degraded lands with low fertility. As production expands on these lands, commercial pressures makes fertilization more likely.

ECOLOGICAL IMPACTS OF INCREASED FERTILIZER USE

Widespread fertilizer use has strong links to deterioration of soil, water, and air quality and release of GHG emissions. For example, on average 60 percent of nitrogen applied to soil is lost as atmospheric emissions or enters surface and groundwater systems, thereby jeopardizing drinking water quality (Crutzen et al., 2008). Nutrient loading in surface waters spawns algal blooms and hypoxic (low oxygen) conditions, culminating in “dead zones” and destruction of aquatic life. About 146 dead zones exist worldwide, including along coasts of China, Japan, and the Gulf of Thailand (EPI, 2004). Pollution of groundwater affects the quality of drinking water.

The atmospheric emissions from nitrogen-based fertilizers lead to the production of nitrous oxide, a GHG with a global warming potential 310 times that of CO₂ (IPCC, 2007). Crutzen et al. (2008) analyzed energy crops’ potential to reduce GHG compared to conventional fuels. Low-input crops like switch grass, elephant grass, and other lignocellulosic feedstocks show significant reductions in GHG emissions. Sugarcane has slightly reduced overall GHG emissions, but net GHG emissions from rapeseed and maize are higher.

The demand for fertilizer also has impacts resulting from its manufacture. According to the US EPA, fertilizer manufacture leads to the release of nearly 46 pollutants in the United States, with ammonia and phosphoric acid accounting for 89 percent of the total volume. Atmospheric ammonia plays a big role in eutrophication. Phosphoric acid in air causes human respiratory problems. Both pollutants lead to soil acidification.

CONCLUSION

Biofuel production systems are similar to high-intensity agricultural systems in that fertilizer usage translates into higher yields and improved economic returns. If biofuels feedstock growers follow conventional practices and apply greater amounts of fertilizers, an increase in biofuels

¹⁰ Eutrophication is the process by which water bodies (lakes, streams, oceans, etc.) receive excess nutrients that stimulate excessive plant growth. The plant growth (e.g., an algal bloom) reduces dissolved oxygen, causing other organisms to die.

Table 19. Fertilizer Requirements for Commonly Used Energy Crops

CROP	Farmer use ¹				Research optimal ¹			
	Maximum Yield (tons/ha)	Nitrogen (kg/ha)	Phosphorus Oxide (kg/ha)	Potassium Oxide (kg/ha)	Maximum Yield (tons/ha)	Nitrogen (kg/ha)	Phosphorus Oxide (kg/ha)	Potassium Oxide (kg/ha)
Cassava ⁵	11	25	50	15	30	40	50	80
Maize ^{2,3,5}	6.4	105	42.6	40.6	8.8	165	77.5	77.5
Soybean ^{2,3}	4.4	97	44	22.5	8	200	80	40
Sugarcane ^{2,3,5}	72.86	117	57.66	110	92	145	150	57
Wheat ^{2,3}	6.7	142	75	38	8.9	182	50	38

1. Source: FAO website: <http://www.fao.org/landandwater/agll/ipnis/index.asp>. In cases where data from multiple countries was available for a crop, the average of the data is presented.

2. China data 3. India data 4. Indonesia data 5. Vietnam data 6. Thailand data.

production will create a greater demand for fertilizers, exacerbating negative environmental impacts. In the push to achieve greater yields, best practices need to be followed that minimize the need for fertilizer application (e.g., non synthetic fertilizers and the use of residues as compost).

6.2 ECONOMIC SUSTAINABILITY

The economic performance of biofuels can be evaluated from both a private and a social perspective. From a private standpoint, assessing the economic performance of biofuels is equivalent to assessing financial viability as measured by profitability. From a social perspective, the economic performance of biofuels is a function of the overall contribution to society's well-being, or what economists refer to as social welfare. A comprehensive evaluation of the social welfare performance of biofuels includes the fuels' net impacts on household income, producer profits, government finance, environmental quality, and energy security. This section explores the economic relationships among agriculture, energy, and biofuels, and addresses the economic competitiveness of biofuels and their social welfare impacts. It also reviews policies to promote biofuels.

6.2.1 FINANCIAL VIABILITY OF BIOFUELS FROM A COMMERCIAL PERSPECTIVE

Since feedstocks are the most significant portion of biofuels production cost, profitability depends on whether on the price of feedstocks are low in relation to the price of crude oil. Generally, many biofuels are not cost-competitive with fossil fuels, even with subsidies. Because of high oil and food price volatility, boom and bust cycles have made the biofuels industry both risky and uncompetitive.

INTER-LINKAGES AMONG BIOFUELS, OIL, AND FOOD MARKETS

The relationship between biofuels, oil, and food markets is complex. In energy markets, biofuels are direct competitors with petroleum-based petrol and diesel. In agricultural markets, often biofuels processors compete directly with food and animal feed processors.¹¹ An individual farmer is indifferent to the end use a prospective buyer intends for the crop. Farmers sell to biofuels processors if the price is higher than what they would obtain from a food processor or an animal feed operation. Because energy markets are large relative to agricultural markets, a small change in energy demand implies a large change in demand for agricultural feedstocks, raising concerns about food prices and food security, particularly in developing countries.

11 However, sometimes the buyer of a food crop or biofuels feedstock can be one and the same. For example, sugarcane growers can sell to a processor that makes both sugar and ethanol.

Strong global growth in demand has caused food crop-based, first-generation biofuels to become a significant consumer of food crops. As a result, biofuels production has begun to shift demand curves for food crops, increasing prices in affected markets (Collins, 2008; Mitchell, 2008). Further, due to high substitutability among major food crops and globally integrated markets, biofuels production also affects non-biofuels crops. Higher food crop prices in turn increase the feedstock cost for biofuels production.

Before mid-2004, crude oil prices were so low that many biofuels feedstocks could not compete, even with subsidies. From 2004 to 2006, as oil prices rose, the economics for biofuels were favorable. When crude oil prices initially began to rise, agricultural feedstock prices were still low; biofuels became cost-competitive and investments shot up. By 2007, oil prices and increased demand for food, among other factors, raised agricultural feedstock prices by 184-254 percent for wheat, corn, coconut, soya, oil palm, and sweet sorghum, eroding profit margins. By 2008, many biofuels plants were shut down or idled to cut operating losses, especially in those plants that did not have secure long-term access to cheap sources of feedstock. These trends precipitated what is called the biofuels bubble (**Box 8**). By 2009, oil prices came down to around USD \$50 per barrel, but many biofuels are still not competitive.

Alternately, a sudden decline in oil and biofuels prices can have devastating effects on feedstock production margins. Southeast Asian palm oil provides an example of the impact of price volatility (**Figure 16**). As oil prices crashed towards the end of 2008, palm oil fell from a high of around \$1,200 per metric ton to under \$450 per metric ton (Aglionby, 2008). Prices of palm oil in November 2008 were close to smallholder production costs, so many smallholders were on the edge of bankruptcy.¹²

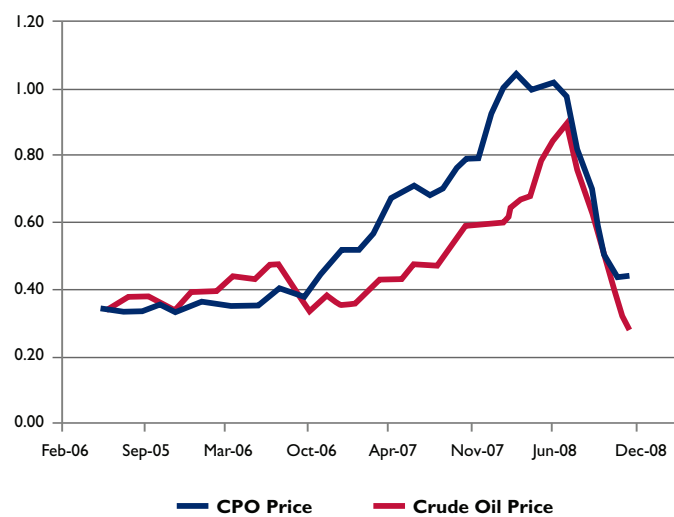
Smallholders constitute about 30 percent of palm output in Malaysia and 25 percent in Indonesia, but larger companies are more likely to be able to ride out the downturn.¹³

PRODUCTION COSTS

Figure 17 provides a breakdown of production costs

of biofuels produced in the US, EU, and Brazil. Costs are broken down by feedstock, processing and energy costs, and the value of co-products. These are shown in comparison to the net production costs. Changing oil price has a significant impact on the spread between the production cost of biofuels and the market price for fossil fuels. By far the lowest production costs are in Brazil, both for sugarcane-based ethanol and for soybean-based biodiesel; only Brazilian sugarcane ethanol consistently costs

FIGURE 16. Prices of Crude Palm Oil and Crude Petroleum Oil 2005-2008 (US\$ per liter)



Source: GSI, 2008b

less than the market price for gasoline. For all the selected biofuels, feedstock prices constitute the largest share of total production cost. In general for first-generation biofuels, feedstock costs are 60-90 percent of total production costs (Deutsche Bank, 2008; IEA, 2006). Important to note is that in Brazil, energy costs are negligible because bagasse is co-fired for process energy and ethanol is used to transport raw materials and the finished product. EU and US producers, rather, will sell the co-products (e.g., dry distillers grains, or DDG), usually for animal feed, which adds an additional revenue stream (**Box 9**).

In Asia, production costs vary by feedstock and country. **Table 20** provides a selection of production costs from 2006-2007. It is important to note that since costs vary

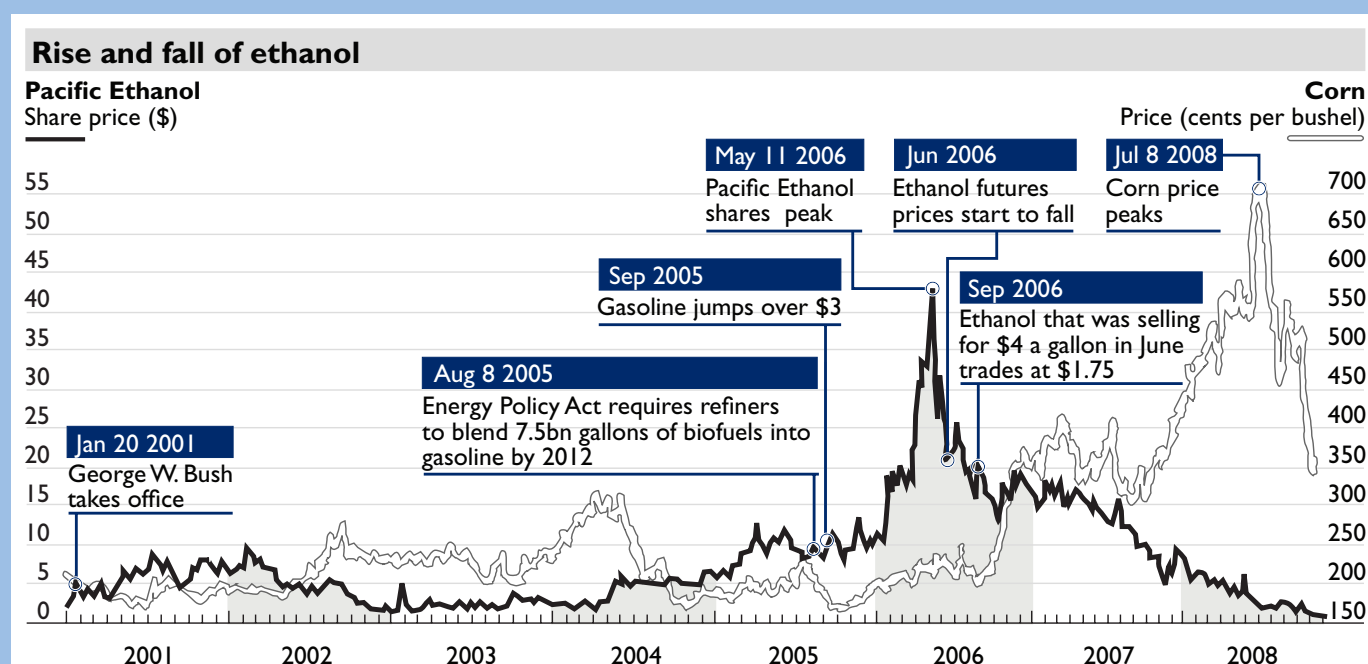
¹² Smallholders are small-scale farmers.

¹³ In the wake of the slump, Indonesia and Malaysia have announced plans to stimulate demand through biodiesel mandates. To cut production costs, Malaysia has also eliminated the import duty on fertilizers and aims to slash fertilizer prices by an additional 15 percent.

Box 8. The Boom and Bust Cycle of Biofuels Investments

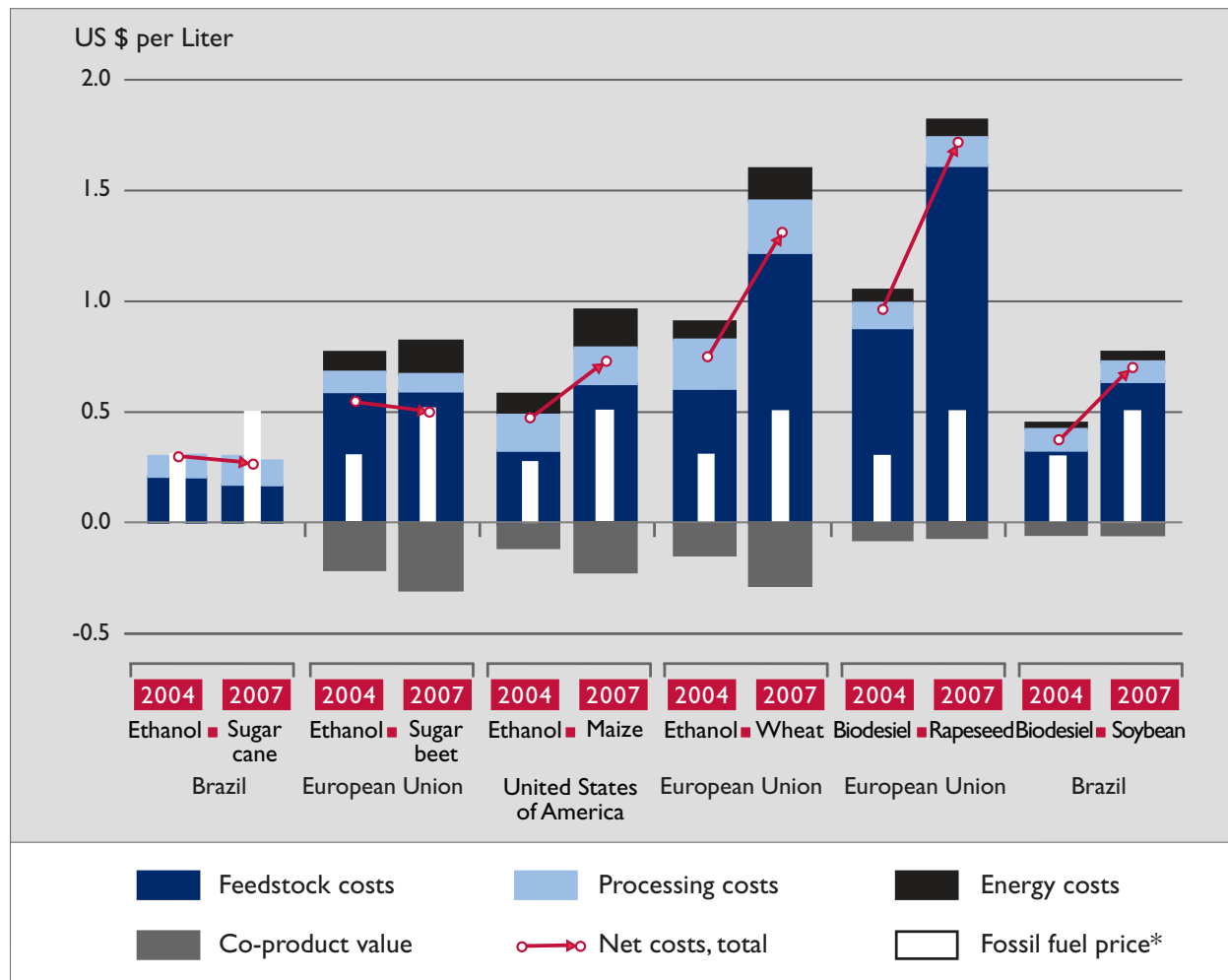
The volatility in the biofuels industry is illustrated by ethanol investment cycles in the United States and Southeast Asia. By mid-2005, oil prices exceeded \$60 per barrel, and US corn ethanol was almost competitive without subsidies (FAO, 2008). The targets in the US Energy Policy Act of 2005 resulted in a rush of ethanol distillery construction. As the demand for corn shot up, prices rose throughout 2006. Corn ethanol struggled to stay competitive, and many plants began operating at negative margins. When crude oil climbed to US \$135 per barrel by mid-2007, corn ethanol regained competitiveness, but corn prices were at all-time highs, close to US \$8 per bushel. This had a dramatic impact on the financial performance of ethanol companies. After targets were introduced, Pacific Ethanol's peak share price mirrored the boom driving US ethanol investments. However, as feedstock prices peaked in 2008, companies that hedged against rising prices saw profits collapse, and several companies were in financial turmoil. This led to stranded assets and a drop in ethanol production. Following the drop in demand, corn prices dropped to around US \$4 per bushel.

THE RISE AND FALL OF ETHANOL



Source: Financial Times, 2008

Southeast Asia's palm oil biodiesel industry underwent a similar cycle. It became immensely profitable beginning in 2002, when the spread between crude oil and crude palm oil (CPO) favored palm oil. As biodiesel demand increased, investments and production expanded in Indonesia and Malaysia. In 2005, the price favorability reversed. By late 2007, the high cost of oil still did not offset the high CPO cost, and plants began to close. In Malaysia, 92 licenses were approved for biodiesel facilities in 2006 and 2007, but only 14 facilities were built, of which eight are now operating, producing at less than 10 percent of total capacity (GSI, 2008b). RaboBank has warned of a surplus capacity of 1 million MT in Asia by 2010.

FIGURE 17. Biofuels Production Costs in Select Countries, 2004 and 2007

Source: FAO, 2008

with the price of oil and feedstock, these are representative and do not necessarily reflect current production costs. The difference in production costs by feedstock show that different countries have different operating conditions and there is no clear winner from a production cost perspective. In general, ethanol from molasses and biodiesel from oil palm and waste oil can have some of the lowest production costs. Most Asian biofuels compare favorably against higher production costs in the US and EU.¹⁴

A 2006 FAO study that calculated breakeven prices for selected feedstocks at different crude oil prices revealed a wide variation in the ability of different production systems to deliver biofuels competitively. Brazilian sugarcane was more competitive at much lower crude oil prices

than other feedstocks used around the world. Tyner and Taheripour (2007) in FAO (2008) published an analysis of breakeven points for maize-based ethanol, given various combinations of feedstock and oil prices.

In **Figure 18** the solid black line traces the various breakeven points for maize-ethanol in the United States. For example, at US\$80 a barrel for crude oil, ethanol processors can pay up to US\$120/metric ton for maize and remain profitable. At price combinations located above and to the left of the parity price line, maize ethanol is profitable. At lower crude oil prices or higher maize prices (combinations below and to the right of the solid line), maize ethanol is not profitable.

¹⁴ These production costs are from 2006-2007 before feedstock prices rose significantly; some biofuels were competitive with gasoline and diesel at these prices.

Box 9. Use of Co-products

One important aspect of biofuels economics that improves financial viability is the use of co-products. All first-generation feedstocks have valuable co-products that can either be used in biofuels processing or sold for additional revenue. Crop production results in residues, such as bagasse and palm fronds, which can be used in cogeneration plants to produce heat and electricity. Biodiesel processing results in glycerin, which has uses in many industries, including the food, beverage, and pharmaceutical industries. Other high-value by-products include silage, DDG, and oilseed cake that can be used for animal feed, and as fertilizer. Utilization of these co-products can make an important contribution to the financial returns at biofuels plants. For example, DDG can add as much as 10-15 percent to ethanol producers' incomes (USDA, 2007).

Table 20. Selection of Biofuels Production Costs (2006-2007)

Country and Feedstock	Production Cost (USD per liter)
China: corn	\$0.56
China: cassava ¹	\$0.47
Thailand: cassava	\$0.54
India: molasses	\$0.30
Thailand: molasses	\$0.46
Indonesia: oil palm	\$0.41
Thailand: oil palm	\$0.86
Malaysia: oil palm	\$0.54
Philippines: coconut	\$0.85
China: waste oil	\$0.41
Thailand: waste oil	\$0.68
Gasoline Refinery Costs	\$0.42-\$0.56
Diesel Refinery Costs	\$0.64

Source: APEC, 2008; Tantichaoren, 2007; Philippine Coconut Authority

1. In contrast, in 2008, cassava-based ethanol in Thailand was reported at around \$0.60 per liter

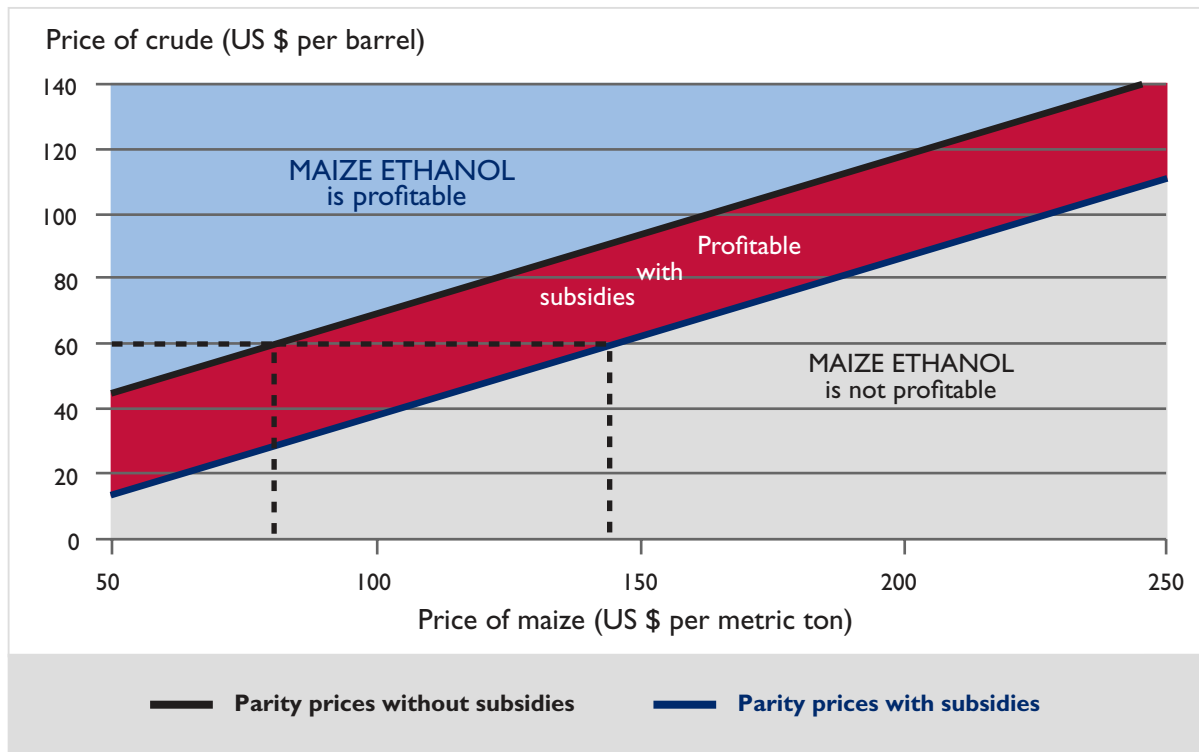
Exchange rates used in table: 0.131 CNY/USD; 34.5 Baht/USD

The parity line (blue line) shifts to the right and below of the original parity line (black line) when taking into consideration various government support schemes (e.g., tax credits, tariff barriers), depicted here based on a combined subsidy of about US\$63 per metric ton of maize. For crude oil priced at US\$100 a barrel, producers are able to pay up to US\$183 per metric ton for maize. FAO (2008) cites an earlier FAO study based on average feedstock prices prior to 2006 that confirms that different systems have a wide variation in break-even prices: Brazilian ethanol—competitive at just over US\$30 per barrel—out-competes maize at roughly US\$57 per barrel and mixed European feedstocks at US\$80 per barrel. Correspondingly, Deutsche Bank (2008) estimates that oil palm-based biodiesel is competitive at oil prices over US\$80 per barrel without subsidies and at US\$60 per barrel with current subsidy rates.

CONCLUSION

In general, Asian biofuels are competitive with biofuels from other regions. They are, however, competitive with petroleum-based liquid fuels only when feedstock prices are relatively low compared to oil prices. Except for Brazilian ethanol, generally, unsubsidized biofuels are not competitive with fossil fuels. Even if Brazil's profitability can be replicated, it likely will take years for mature markets to develop in Asia. Absent declines in production cost, biofuels will require substantial subsidies and other support mechanisms to be competitive.

The tenuous nature of biofuels profitability is evidenced by the adverse conditions in input and output markets in 2008 that drove many biofuels firms into bankruptcy. Because of such volatility, policies may be needed to induce biofuels investments.

FIGURE 18. Breakeven Prices for Corn (Maize) Ethanol and Crude Oil with and without Subsidies

Source: Tyner and Taheripour, 2007 in FAO, 2008

6.2.2 ECONOMIC VIABILITY OF BIOFUELS FROM A SOCIETAL PERSPECTIVE

An economic analysis of biofuels based on market prices alone is insufficient to assess the desirability of biofuels for society as a large-scale energy source. The main reasons are the ubiquitous distortions of the fossil fuel and biofuels markets, and the repercussions of biofuels production for other sectors. To inform public policy, a private market perspective must be complemented by a social welfare perspective that evaluates the impacts of biofuels on society as a whole.

From a social perspective, the economic performance of biofuels is a function of overall contribution to society's well-being. Overall, biofuels are found to lower social welfare if they result in food prices increases because food prices affect the poor more than energy prices. Because of uncompetitive production costs and the need for subsidies and other financial support along the production chain, first-generation biofuels are not found to be a cost-effective avenue to reduce GHGs, fossil fuel-based transport demand, or foreign imports. Furthermore,

trade opportunities for biofuels will be limited as long as countries enforce trade tariffs and protectionist policies.

WELFARE ANALYSIS OF BIOFUELS

The social benefits of biofuels production are harder to assess than commercial profitability. Determining biofuels' impact on aggregate social welfare requires an evaluation of their impact on input markets (specifically, food crops, land, labor, and agro-chemicals), the environment, energy and food security, the macroeconomy (government budgets and balance of trade), and income distribution. The analysis is complicated by the absence of comparable values for difficult-to-quantify social assets, such as environmental amenities and energy security. Another complicating factor is the temporal structure of the distribution of benefits and costs associated with biofuels strategies. For example, benefits from climate change mitigation are spread over long time periods while the costs of a large-scale switch from conventional energy towards biofuels or other renewable sources are heavily biased toward the present and near-term.

Analyses of the US ethanol program suggest that the recent expansion of corn ethanol slightly lowered global gasoline prices, although the decrease was too small to be noticed given the steep rise in oil prices (Sexton et al., 2009). However, a larger increase in food prices resulted. From a distributional perspective, the poor experienced a negative impact from the increase in food prices that was larger than the benefit from the decrease in gasoline prices (*ibid*).

Ex ante assessments of policies, such as national biofuels mandates, using more comprehensive computable general equilibrium models—the most widely-used economic tools for performing welfare analysis of government policies—suggest increases in social welfare from reduction in energy prices are overcompensated by negative impacts of increased food prices (Elobeid et al., 2006; Dixon, 2007; McDonald, 2007). Although these studies focused on the US and the EU, they suggest that negative welfare impacts are even larger for developing countries, which benefit less from lower oil prices and are hit harder by higher food prices. These results suggest that policymakers should exercise caution in legislating biofuels mandates, although intervention in biofuels markets may be justified for other reasons. For one, these studies do not consider possible benefits of biofuels to the environment or energy security.

Government intervention in favor of biofuels can be justified from two perspectives. One is the normative view that in cases of market failure, government intervention is justified to achieve welfare improvements. Market failure can occur because of externalities, imperfect competition, or public goods.¹⁵ The second rationale is based on considerations of political economy, such as agricultural and trade objectives, support for infant industries, and energy security (guarantee of stable supplies). The following section examines these two rationales in more detail.

MARKET FAILURE CONSIDERATIONS: ENVIRONMENTAL AND ENERGY SECURITY EXTERNALITIES

Two market failures commonly used to justify government action are environmental and energy security concerns.

Government interventions to address environmental externalities have the stated goal of correcting or reducing negative, uncompensated welfare impacts from pollution or natural resource damages (e.g., emission of air pollutants or greenhouse gases) by providing incentives and mandates for producers and consumers. The welfare enhancement of government interventions promoting biofuels is still debated. On the one hand, biofuels currently are a very expensive method of reducing air pollutant and GHG emissions. For example, according to a GSI (2008d) study, under optimistic projections it costs roughly US\$500 in federal and state subsidies to reduce one metric ton of GHGs in the US through the production and use of corn-based ethanol.¹⁶ Doornbosch and Steenblik (2007) estimated that the cost of biofuel-based GHG abatement can be as high as US\$4,520 per metric ton in the EU for ethanol from sugar beet and maize—magnitudes higher than the market price of carbon dioxide-equivalent offsets. The IEA (2004) estimates that CO₂ abatement from most biofuels costs well over US\$100/tCO₂-eq, with Brazil as an exception with costs of US\$20-60 per ton CO₂-eq on a gasoline energy equivalent basis.¹⁷ In addition, as discussed in **Section 6.1.1**, studies show net GHG emission reductions are not achieved when converting forest and grasslands into first-generation biofuels until decades or centuries into the future, thus making most biofuels a doubtful proposition for reducing GHGs in the near- to medium-term.

Energy security is a significant concern in the region for two principal reasons—first, the unpredictability of the price of imported fuels that can lead to crippling bills and, second, rising demand globally and regionally. Considering that fossil fuels provide more than 75 percent of final energy demand in China, India, Indonesia, Thailand, the Philippines, and Vietnam, and oil import dependence in Southeast Asia is expected to rise to 70 percent by 2030, it will be important for countries in the region to pursue energy security options that shore up domestic supplies in an efficient, affordable, and sustainable manner (APEREC, 2006). The analysis in **Section 5** suggests that biofuels will account for between 3 and 14 percent of transport fuel in the focus countries

¹⁵ A good is considered public if, once provided, no one can be excluded from its consumption, and if its consumption by one individual does not impact its consumption by others. National defense, a stable climate and clean air are examples of public goods.

¹⁶ That same investment could buy 30-140 metric tons of GHG emission reductions from other project types on the EU Emissions Trading Scheme (ETS) or Chicago Climate Exchange (CCX) carbon exchanges. (CCX is a voluntary carbon exchange based in the US).

¹⁷ Environmental groups in Europe have taken aim at the ten percent target for blending biofuels in transport fuel, pointing out that the goal would only lead to a one percent reduction in emissions across the EU while the same investment, if redirected to other types of reduction projects, such as forestry, could achieve reductions of up to 30 percent (PointCarbon, 2008).

by 2030, up from less than an average of 3 percent today. Biofuels cannot significantly bolster the energy security of the largest oil-importing countries in Asia.

While reducing dependence on foreign oil was the primary reason behind the Brazilian and US ethanol programs, economists have long recommended that the primary policy response should be to correct foreign exchange distortions before promoting import substitution or export subsidization. Allowing domestic fuel prices to reflect international market prices would better curb demand, aided by policies that promote vehicle efficiency and reduce car ownership growth rates (Rajagopal and Zilberman, 2007). Furthermore, with vehicle ownership rising by 1.7 percent per year in developing Asia, biofuels are likely to make only a negligible dent in reducing overall demand for transport oil (ADB, 2006).

POLITICAL ECONOMY CONSIDERATIONS: AGRICULTURAL AND TRADE POLICIES

Because production costs of biofuels are generally significantly higher than those of fossil fuels, the agricultural and trade policies that influence supply, demand, and agricultural prices are the chief determinants of biofuels viability and expansion. Among policy interventions, agricultural policies in the form of price subsidies and regulation of imports and exports influence trade opportunities and often result in distortions.¹⁸

The debate over trade restrictions centers on the fact that potential export markets like the US, EU, and Canada support local feedstocks—wheat, corn, sugar beet, and vegetable oils—to produce biofuels that avoid GHG emissions (see **Section 6.1**) and are costlier to produce. In practice, this locks out Asian biofuels that may in some cases offer greater GHG savings (OECD, 2008a). The policies may be damaging in the long run, since price interventions typically are short-term solutions to volatility and introduce new economic distortions. Ideally, GHG reductions should be realized through the least-cost options regardless of location (**Box 10**). Protectionist policies significantly limit trade prospects for Asian-

produced biofuels but are difficult to change because of the political influence of agricultural lobbies.

In theory, biofuels trade liberalization would increase competition, allowing the world's lowest-cost producers to expand market share.¹⁹ Removal of high tariffs would reduce prices and increase demand for biofuels in highly protected markets. However, in reality, breaking down trade barriers while maintaining current agricultural policies (and associated subsidies) could aggravate market distortions, as the total market size for subsidized biofuels would increase. Reducing trade barriers would open up markets to Asian biofuels producers, but the extent to which they could take advantage of this potential depends on the competitiveness of their biofuels with fossil fuels, crude oil price fluctuations, and the ability to develop significant export capacity. Within Asia, only Indonesia and Malaysia have significant export capability (Kojima et al., 2007; IIED, 2008). India and China have plans to import biofuels to meet their requirements, while others, like Thailand, are focusing solely on domestic production. Prospects for regional biofuels trade depend on the extent to which countries boost export production.

POLICY MECHANISMS FOR PROMOTING BIOFUELS

A range of national agriculture, energy, fuel, and trade policies influence biofuels development. Policies generally are employed in the form of product standards (fuel blends), R&D policy, or financial incentives such as production or fuel blend tax credits, investment subsidies such as low-interest loans, direct subsidies, export subsidies, or import tariffs.

Figure 19 shows points in the supply chain where direct and indirect policy measures can provide support.

Agricultural policies, including subsidies and price support mechanisms, affect production levels and feedstock prices. Blending mandates are a key driver in most Asian countries.²⁰ Policies are in flux as countries occasionally revise mandates and targets in response to volatile crude oil prices and concerns about feedstock availability. Governments also encourage biofuels distribution and use

¹⁸ Import tariffs are listed in Table 7 in Section 4.

¹⁹ The lowest-cost producers are not necessarily the most efficient ones, as the low cost may be the result of externalities caused by a lack of environmental or labor regulations rather than inherent efficiency advantages.

²⁰ In 2007, around 60 countries had adopted renewable fuel support programs, including 23 developing countries (REN, 2008)

Box 10. EU Biofuels Import Restrictions

To meet an interim target for 5.75 percent of transport fuels from biofuels, the EU has been a large importer of biodiesel. However, the EU has mandated that imports demonstrate GHG savings of 45 percent or more compared to petroleum-based fuels. EU studies conclude that palm oil yields GHG reductions of less than 35 percent. Malaysia and Indonesia are fighting these policies, which they say are political rather than science-based. Malaysia argues the EU policy is a front for domestic protectionism, citing studies from the Malaysian Palm Oil Board that suggest that palm oil in Malaysia is produced sustainably and reduces GHGs by at least 50 percent (Basiron, 2008).

by subsidizing or mandating investments in transport and storage infrastructure, and promoting the purchase of flex-fuel vehicles. Tax incentives and exemptions are intended to stimulate domestic production, and tariffs as described above are aimed at protecting domestic industries and producers. Some Asian countries, notably Indonesia, impose an export tax on biofuels to generate revenue. Most countries that produce biofuels also support research and development through public funds, especially in areas related to crop agronomy, cellulosic ethanol technology, microalgae-based biodiesel, and biomass-to-liquid (BTL) processes.

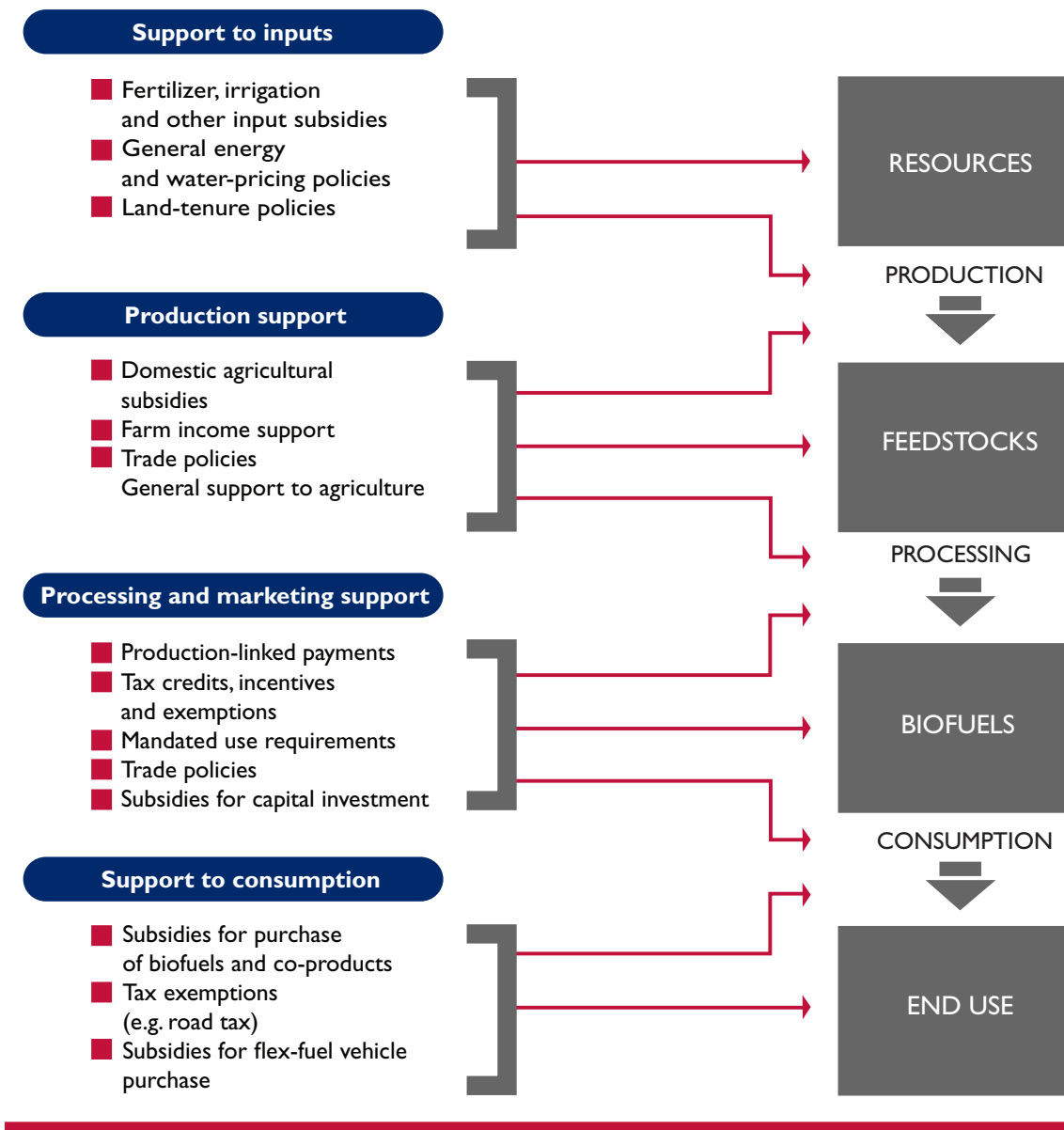
These policies can have variable impacts on policy goals, including reduction in use of petroleum fuels and GHG emissions. Generally, mechanisms that impact supply through price supports, land-use regulation, and regulation of imports and exports have larger market-distorting effects than R&D support. National blending requirements, renewable fuels targets, and direct subsidies are the most common form of support and consequently the primary drivers of increasing production.

Subsidies for biofuels have increased significantly, especially in OECD countries. In the US, processors and growers receive more than US\$6 billion per year, and those in the EU receive almost US\$5 billion per year. These levels could increase as subsidies are often linked to mandated outputs that are set to increase in the near term. Ethanol subsidies range from US\$0.30 to US\$1.00 per liter across the OECD, while subsidies for biodiesel range from US\$0.20 to US\$1.00 per liter.

Similarly, several countries in Asia have subsidies to stimulate production. Because of the indirect effects of some mechanisms (e.g., biofuels use mandates) and lack of data, calculation of total subsidies is difficult and has only been done for a few countries. **Table 21** shows subsidies offered to biofuels in select focus countries. The bulk of the subsidies are tied to output. Thus, if double-digit growth of the industry continues, total government spending on biofuels will skyrocket.

It is unclear whether current subsidy levels for biofuels production in Asia are economically justifiable given the large financial costs to governments and unstable profits in the biofuels market. For example, in Malaysia, when the market price for palm oil and Malaysian crude was US\$870 per ton and US\$115 per barrel, respectively, biodiesel production costs were roughly US\$0.20 higher per liter than petroleum diesel (GSI, 2008c). In 2008, the Malaysian government spent an estimated US\$7.8 billion on petroleum fuel subsidies. Replacing petroleum diesel with biodiesel would actually raise the government's subsidy burden, rather than lower it. A proposal to displace conventional diesel with 5 percent biodiesel (B5) would add an additional US\$122 million to the subsidy bill, and the government cancelled plans to introduce this mandate when palm oil prices reached highs in 2007 (GSI, 2008c). On the other hand, if the price of palm oil fell to pre-2006 levels and oil prices rose to US\$175 per barrel, a B5 mandate would reduce government subsidies by around US\$430 million (ibid). When palm oil prices fell in late 2008, discussions about a biodiesel mandate resumed.²¹

21 The biofuels industry's lack of economic viability in Malaysia due to high palm oil prices was further demonstrated when, by September 2008, only 14 functional biodiesel plants were constructed in the country although 92 licenses had been issued in 2006-2007. Of the 14 plants constructed, only eight were actually producing biodiesel (GSI, 2008c).

FIGURE 19. Support Provided at Different Points in the Biofuels Supply Chain

Source: FAO (2008)

The Chinese government paid at least US\$115 million—or about US\$0.40 per liter—in biofuels subsidies in 2006. Payments are expected to grow to US\$1.2 billion by 2020 although this figure may be substantially underestimated (GSI, 2008a). The government has said biofuels will not be allowed to jeopardize food production. It is in the contradictory position of both trying to discourage food crops in biofuels production and continuing to provide production subsidies for ethanol from corn, wheat, and other crops.

From a welfare perspective, there is concern that mounting domestic support for biofuels farmers boosts production above market equilibrium, artificially depressing world prices, resulting in worsening price volatility, and ultimately, reducing the scope for competition from imports (ESMAP, 2005). For example, about 80 percent of worldwide sugar production is subsidized—only Brazil, Australia, and Cuba have sugar sectors operating at international market prices. India, China, and Thailand keep sugar prices high through minimum prices, quotas, and import restrictions (ESMAP,

Table 21. Subsidies for Biofuels in Selected Asian Countries

COUNTRY	Total Subsidies for Biofuels (US\$ unless indicated otherwise)
China	Roughly US\$220 million in 2007; blending credit of 1,373 Chinese Yuan (CNY) per ton of ethanol in 2007 + tax exemptions and low-interest loans for capital investment; no official subsidies for biodiesel
Malaysia	US\$16 million in low interest loans; US\$3.3 million in federal grants
Thailand	24.9 Thai baht (THB) per liter blending credit for ethanol—retail E20 is sold at 6 baht per liter lower than premium pure gasoline; tax incentives for E85 vehicles; 30 THB per liter blending credit for B2 manufacturers;
Indonesia	Indonesia Rupiah (IDR) 1 trillion interest rate subsidy to farmers growing jatropha, oil palm, cassava, and sugarcane; IDR 563-572 per liter to Pertamina for distributing biofuels; excise duty cuts
India	90% subsidy for jatropha irrigation; 30% for oilseed production facilities; fertilizer subsidies
Philippines	Raw materials exception from VAT and favorable loan policies

Sources: Runge, 2008; NDRC, 2006; GSI, 2008a; GSI, 2008d; TERI, 2005; Alfian, 2009

2005). These supports distort trade and are costly for governments. A mid-1990s study found that Indian sugar subsidies would cost the economy about US\$2 billion a year by 2004 (Larson and Borrell, 2001, as cited in Kojima and Johnson, 2005).

CONCLUSION

Biofuel policies can be based on and directed toward advancing a variety of social objectives. These may include reducing the cost of transportation fuels, improving energy security, furthering rural revitalization, and reducing air pollution and greenhouse gas emissions. While biofuels have had some positive impacts on advancing some of these goals (e.g., farm income and job creation), they also have had some notable disadvantages, such as increasing food prices and government debt. The impact on other policy goals is still unclear, such as the cost of transport fuels, local air pollution, and GHG emissions. Given that these potential impacts vary so greatly—whether positive or negative, to what degree, or unknown—it will remain critical for decision-makers to take a holistic view when designing biofuels policies in the future.

Generally, biofuels and the instruments currently most used to support them are neither the most efficient nor the most cost-effective approaches to achieving any of

these objectives. A carbon tax, one of the most efficient tools to correct the problem of externalities in energy production and use, remains politically implausible. Energy efficiency and conservation, as well as public transportation, can also achieve policy goals without the unintended negative welfare impacts associated with biofuels. The subsidies, mandates, and trade policies to support biofuels indicate that considerations of political economy (e.g., farm lobby, rural votes) shape biofuels policymaking. Subsidies, in particular, consume scarce resources and reduce funds available for other more welfare-enhancing public goods like roads, healthcare, and R&D.

6.3 SOCIAL SUSTAINABILITY

6.3.1 BIOFUELS AND FOOD SECURITY

The recent sudden increase in the prices of cereals, edible oils, and fats during 2007-2008 prompted many questions about biofuels. Debates continue over the magnitude to which biofuels have contributed to the rise in food prices, but most sources agree that biofuels played a role. In Asia, ethanol from corn and cassava, and biodiesel from oil palm may have had an impact on the price of food, feed, and edible oils, respectively. Impacts of higher demand for biofuels and higher food prices have been both direct and

indirect. Higher food prices affected the poor the most as governments scrambled to keep domestic food prices in check while balancing exports. As acreages dedicated to biofuels feedstocks expanded, displacing other food crops, countries sought out new sources for food. These impacts indicate that biofuels expansion should be based on non-food feedstocks, grown on non-agricultural land.

IMPACT OF BIOFUELS ON FOOD SECURITY

From mid-2007 to mid-2008, the average prices of corn increased by 60 percent, soybeans by 76 percent, wheat by 54 percent, and rice by 104 percent (Runge and Senauer, 2008) **Figure 20**. Between early 2004 and June 2008, FAO's composite food index rose by about 114 percent while the grains and oils components of the index each rose by 178 percent. Several factors may have caused food prices to increase, including: rising affluence in China, India, and other rapidly developing countries leading to increased demand for meat and processed foods; the rapid depreciation of the dollar against the euro and other important currencies; speculative interest from financial players flooding into commodity markets; the increase in the price of petroleum and farm inputs, particularly fertilizers derived from natural gas; and the demand for corn-based ethanol in the US and biodiesel fuels from vegetable oils in Europe.

Several analyses have attempted to quantify the effect of biofuels on rising food costs. The International Food Policy Research Institute (IFPRI) estimates that demand for biofuels accounted for 30 percent of the increase in weighted-average grain prices between 2000 and 2007 (Rosegrant, 2008). Collins (2008) puts the figure at 23-35 percent, while the OECD blames biofuels for about one-third of the projected increase in cereal and oilseed prices over the next decade (OECD, 2008b). In the most aggressive estimate to date, the World Bank reports that as much as 70-75 percent of recent increases in food commodity prices were due to biofuels, either directly or indirectly (Mitchell, 2008).

There have been a few viewpoints opposing the above conclusions. In testimony to the US Congress, the chairman of the Council of Economic Advisers asserted that while the increased ethanol production had driven up prices of corn and soybeans, only 3 percent of retail food price increases were attributed to biofuels (Lazear, 2008). The

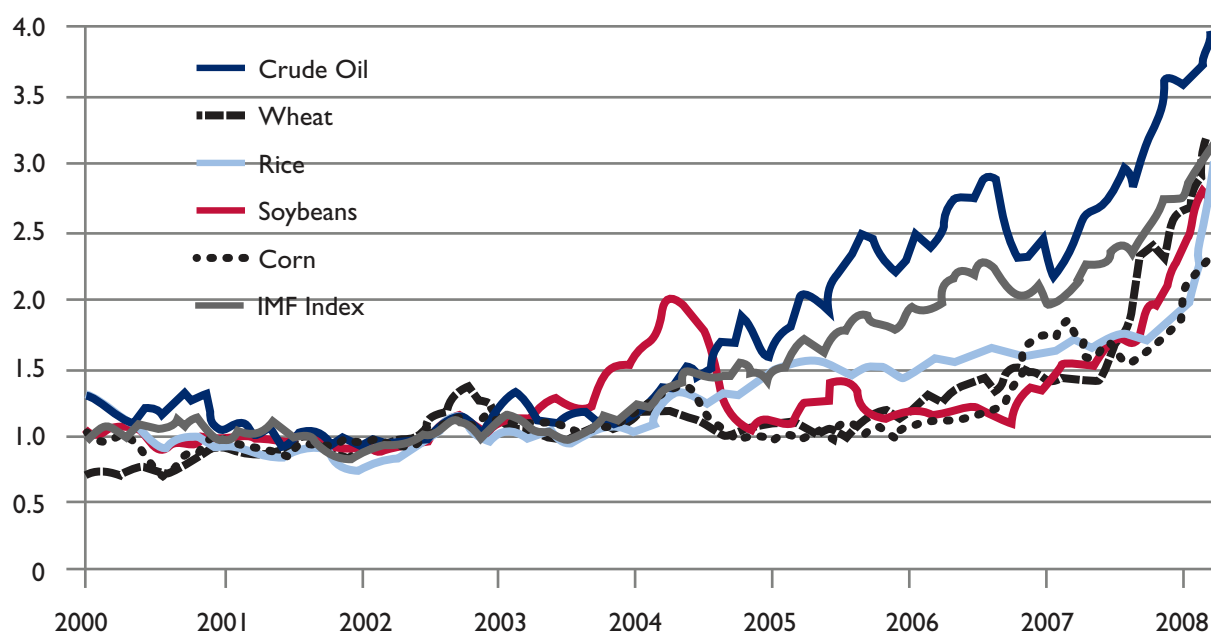
US Department of Agriculture echoed these conclusions, estimating overall impact on food prices at a mere 0.3 to 0.7 percent of the Consumer Price Index (CPI) (USDA, 2008). An inquiry sponsored by the Asian Development Bank (Timmer, 2008) suggested biofuels production was just one of several factors contributing to food price increases. Overall, while most analyses conclude that the demand for biofuels has contributed to higher prices, the magnitude of the contribution remains a subject of debate.

DIRECT AND INDIRECT EFFECTS

Corn-derived US ethanol illustrates the links between biofuels expansion and food prices. Spurred by the Energy Policy Act of 2005 and related targets for renewable fuels, corn diverted to make ethanol rose steadily from 11 percent in 2004 to an estimated 30 percent in 2008. This increased demand shifted acreage from production of other crops, particularly soybeans, to corn. Between April 2007 and April 2008, soybean prices rose 75 percent, while acreage declined by 16 percent in the US. Such a large shift in land use had far-reaching effects on supply and demand of commodities around the world. As a result of reduced US soybean production, China turned to Asian-produced palm oil for vegetable oil. This demand was overlaid on an increased CPO demand for the European biodiesel market.

The displacement of soybeans also increased demand for rapeseed and other oils to manufacture biodiesel in the EU, which in turn displaced wheat both in the EU and other wheat-exporting countries. The eight largest wheat-exporting countries expanded rapeseed and sunflower acreage by 36 percent (8.4 million hectares) between 2001 and 2007, largely at the expense of wheat (Mitchell, 2008). **Figure 21** shows the diverging relationship of corn and soybean acreage in the US, and of wheat and oilseed elsewhere.

It is likely that biofuels had an impact on food prices in Asia, although to a lesser extent. In May 2007, China implemented a policy to prevent biofuels production on land traditionally devoted to staple grains. China started to look for feedstocks outside its borders, which resulted in new pressure on other crops, especially cassava. Rising cassava imports into China may have contributed to upward pressure on the export price of cassava from Thailand. In 2007, the export price of tapioca starch, an important barometer of the overall cost of cassava products, rose

FIGURE 20. Food and Commodity Prices (2000-2008)

Source: Abbott, Hurt, and Tynder, 2008

Note: Food and commodity price and indices are normalized to equal 1.0, on average for 2002.

by 45 percent, with a similar rise in domestic wholesale prices (Thai Tapioca Starch Association, 2009). Palm oil experienced similar price increases as roughly 10 percent of palm oil was siphoned away from the food supply to make biodiesel.

Increasing food prices are particularly threatening to the world's poorest populations in low-income, food-deficit countries and high prices in 2008 led to food riots in Mexico and Egypt, among other countries. In Asia, where food costs comprise 60 percent of the poor's total household expenditures, economists estimate as many as 1.2 billion people are vulnerable to soaring food grain prices (Rahman et al., 2008).

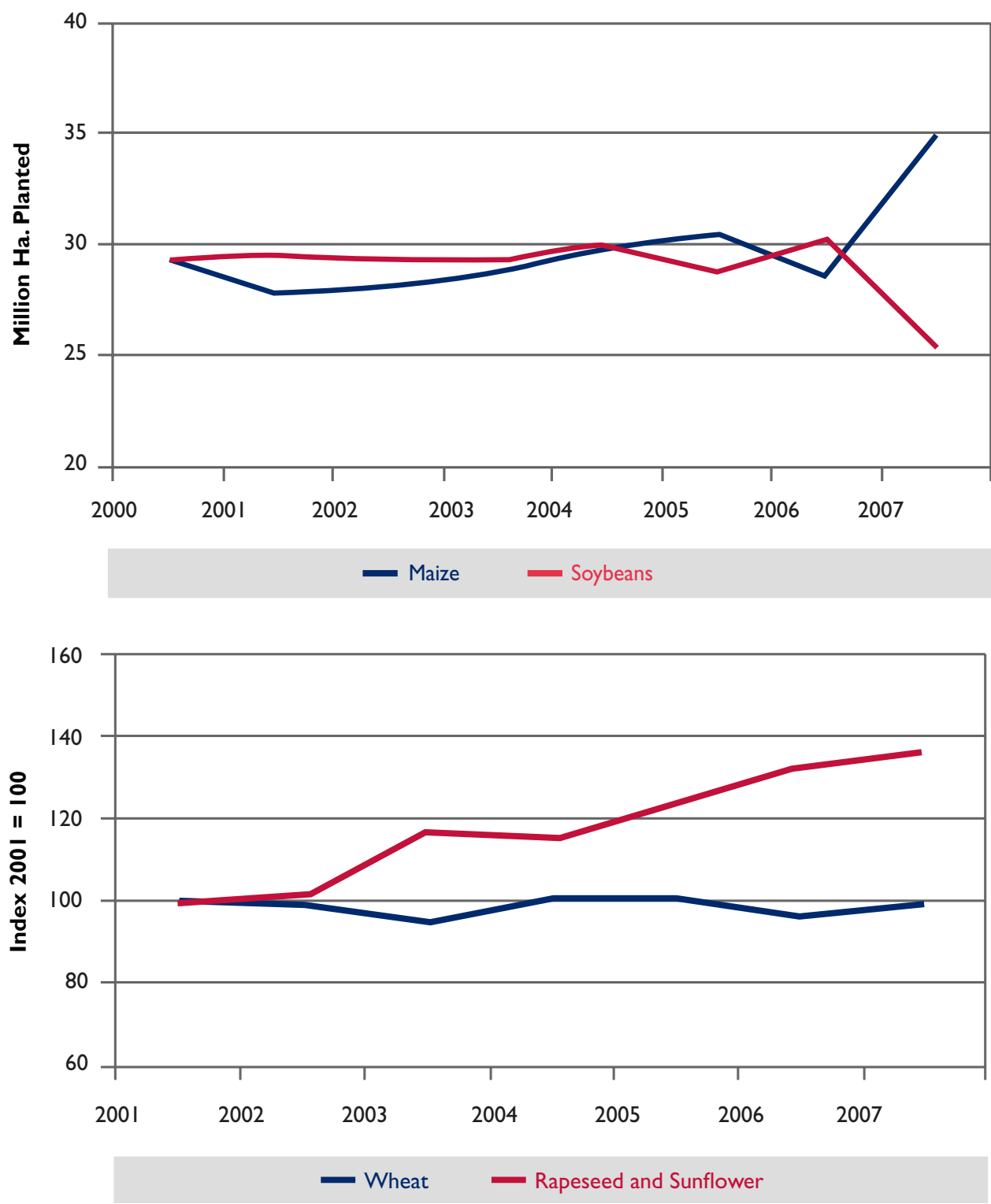
Analyses suggest government policies in Asia have helped insulate domestic markets from global commodity price changes. For example, in Indonesia, demand and speculation drove up the domestic price of crude palm oil (CPO) by 80 percent between mid-2006 and mid-2007. To halt the trend, the government raised the CPO export duty from 1.5 percent to 6.5 percent in June 2007 and reduced the national biodiesel blending mandate (Naylor et al., 2007). Revenues from the import tax were used for INR 325 billion in cooking oil subsidies. When these measures failed

to slow the relentless increase in the price of CPO, the government changed the export duty to a progressive tax. By early 2008, this taxation scheme was revised again. When CPO prices peaked, the export duty stood at 20 percent. Prices then plummeted. In November 2008, the government scrapped the export duty entirely in an attempt to re-stimulate exports.

Because exported agricultural products fetch higher prices than those in the domestic market, Asian countries that export agricultural commodities face the challenge of safeguarding domestic consumers from high commodity prices while trying to boosting export income. Despite their efforts, Asian governments may not always be able to shield their citizens from the most damaging spikes in food prices if international commodity prices continue to rise.

While the impacts biofuels have had directly on Asian food commodity prices have not been quantified, the larger issue is to what extent competition between biofuels feedstocks and food will grow as demand for food rises in the future. Notwithstanding the recent slump in the prices of food commodities, the resumption of economic growth and the underlying increase in population and affluence will lead to renewed competition between food and fuel, putting net

FIGURE 21. Change in Cropping Areas Due to Biofuels Production: US Maize and Soybean Area (top figure); Wheat and Oilseeds Area: Key Exporting Countries (bottom figure)



Source: Mitchell, 2008

food-importers and food-buying households at risk. For example, it is estimated that meeting additional demand for palm oil for food purposes by 2050 would require an additional 12 million hectares of land, assuming yields increase at historical rates (Corley, 2009). This would be roughly double current acreage. As demand for agricultural crops, like palm oil, rises, their use as a biofuels feedstock will become more problematic.

CONCLUSION

In light of the food security impacts described above, Asian countries with ambitious plans for biofuels expansion will need to focus on feedstocks that do not compete with food production, while creating safety nets that protect vulnerable populations from near-term price increases. Biofuels have impacted food prices to a lesser extent in Asia compared to the rest of the world, though overall, food price increases have had some effect and thus care must be taken to pursue feedstocks that pose less of a threat to food crops. From this standpoint, cassava, sweet sorghum, and jatropha are the most promising first-generation feedstocks for biofuels production because they can be grown on dry, marginalized land.

6.3.2. BIOFUELS AND SMALLHOLDERS

In many developing countries, smallholders benefit less from agricultural development than larger landholders do. Smallholders struggle for access to improved planting stock, fertilizers, technical know-how, adequate credit and insurance, and new markets. As a result, smallholders' productivity lags and they are particularly vulnerable to price volatility and poor crop yields. Although, biofuels production systems are more efficient at larger-scales, small-scale systems bring higher employment and income opportunities to rural areas. Biodiesel, in particular, is better suited to smaller scales. The commercial incentive to gain economies of scale needs to be countered by dedicated programs that support smallholders, such as those being implemented in Malaysia and to a lesser extent in Indonesia.

ECONOMIES OF SCALE

Biofuels production, like most agriculture, tends to favor larger-scale operations. Ethanol production is a case in point. Costly, sophisticated processing plants require vast, steady inflows of feedstock to produce fuel at competitive prices (ICRISAT, 2007). Large plantations represent a solution to the need for vertical integration of fuel

production with other processes, such as feedstock supply. A typical ethanol refinery in the Midwestern United States has an annual capacity of 250 million liters, for which over half a million metric tons of corn is required—roughly equivalent to the yield from at least 50,000 hectares (FAO, 2008; Ethanol Industry Outlook, 2007). In Brazil, a typical ethanol plant crushes 2 million metric tons of sugarcane to produce 200 million liters each year, which requires about 30,000 hectares (Goldemberg, 2008). While small-scale farmers can grow crops like sugarcane and corn commercially, economic incentives to concentrate production are significant. The preference is for large, mechanized farming operations that can supply centralized processing facilities.

This is also true, albeit to a smaller extent, for biodiesel. A typical Malaysian biodiesel refinery processes 60 million liters per year, which requires a crop of about 13,000 hectares (data extrapolated from FAO, 2008). While this area is smaller than the requirements for corn or sugar-based ethanol, it is still vastly larger than the average few hectares of a Malaysian smallholder.

Crops that require manual harvesting, such as jatropha and pongamia, are well suited to small-scale cultivation and, in several respects, ill-suited to large-scale production. However, participation in wider markets requires that biodiesel products meet stringent quality standards, which are easier to attain with large-scale production (further discussed in **Section 7.6**).

PROMOTING SMALLHOLDER INVOLVEMENT

Recognizing the need to involve smallholders in feedstock production from a social equity and employment standpoint, many governments have implemented policies to promote smallholder farming. They include making public investments in infrastructure, irrigation, and research; sponsoring innovative approaches to rural finance; and improving markets in rural areas. The Brazilian government, for example, created the Social Fuel Stamp program to encourage biodiesel producers to purchase feedstock from small family farms in poorer regions of the country. Companies that join the scheme benefit from partial or total federal tax exemption. By the end of 2007, some 400,000 small farmers had joined the program to sell oil palm, soybeans, and castor beans to refining companies (Dubois, 2008).

In Asia, government-sponsored contract farming has been relied upon to build markets while safeguarding smallholder participation. Malaysia and Indonesia have put structures in place over the last few decades to cultivate oil palm. According to Vermeulen and Goad (2006), Malaysia's Federal Land Development Authority (FELDA) runs the largest of the government's smallholding schemes. Established in 1956 with a mandate to intensify agriculture and resettle landless families, FELDA has 480 schemes, covering roughly 850,000 hectares (mostly for palm) and more than 112,000 families (www.felda.net.my). The contract system is complex and has changed several times. A new phase in the 1970s changed to a block system, which organized settlers into groups of twenty for cooperative work. Each cooperative operates roughly 80 hectares of oil palm. They receive housing, infrastructure, and agricultural inputs, and each block has 1.5 hectares for subsistence farming. Farmers transport oil palm fruit from their fields to the road; the block then pays for transport to FELDA-sponsored processing facilities. Profit from block sales is divided among members. Farmers receive the title to the land once they have repaid the debts incurred to finance the agricultural inputs, which usually takes a minimum of 15 years.

In Indonesia, between 1978 and 2001, the government provided policy support, with the help of the World Bank, to implement a smallholder scheme known as nucleus-plasma (Perkebunan Inti Rakyat or PIR). Companies developed oil palm plots for smallholders in a "plasma" area around their own plantation or nucleus. Management of plasma plots—generally two hectares of oil palm plus one hectare for other crops—would be transferred to smallholders after three to four years. The scheme was conceived as part of the government's resettlement program, through which Javanese and Sumatrans moved to less-populated islands. Nearly 900,000 hectares of oil palm smallholdings were established under this model. The original apportionment between nucleus and plasma was 20:80, but has tended towards 40:60 over time.

In a typical scheme, holders of the plasma plots are supported through employment and subsistence agriculture in the early years before the palms reach maturity. A smallholders' cooperative manages the plasma area and contracts technical functions back to the nucleus plantation company. Hence, growers often work as laborers on their plots. They receive additional income

through the guaranteed sale of fruit bunches at a price set through a government formula. The nucleus-plasma schemes continue, although government sponsorship of expansion stopped in 2001.

The outcome of these programs has been mixed. The Malaysian smallholder schemes, for example, were rather successful. By 2003, smallholders—both independent and supported by schemes like FELDA—farmed about 40 percent of the total acreage under oil palm plantation in Johor State, and supported smallholders achieved yields close to those of large plantations (Vermeulen and Goad, 2006). Incidence of poverty declined, and the incomes of more than 300,000 families increased dramatically (Simeh, 2001; Zen et al., 2006). In Indonesia, smallholders farmed roughly 37 percent of palm acreage. The PIR model ensured that supported smallholders achieved high yields, but independent smallholders experienced a huge variance in yield and profitability, notably between those few who had technical know-how and the majority who planted low-yielding varieties. High-yield smallholders, by some estimates, enjoyed rates of return on a par or higher than the nucleus estates (Vermeulen and Goad, 2006).

A variety of problems have plagued the Indonesian experience. Unlike the Malaysian scheme set up to stimulate production, the Indonesian plan was mostly a subsistence project to reduce overcrowding in Java and Sumatra (Laquian, 1982). Underfunded planning and ineffective administration often led to poor selection of settlers and inadequate resources in the early phases. Moreover, the settlers moved to distant locations, which led to alienation, ethnic friction with local groups, and frequent disputes over land tenure. Abandonment rates were relatively high. Many smallholders in mature PIR schemes received good incomes, but success depended on the selling price of oil palm fruit (Zen et al., 2005).

Smallholding in Indonesia is limited to two hectares, which provides insufficient income to farmers after they have paid for fertilizers, pesticides, and technical assistance. When debt mounts, farmers are forced to work for the plantation company (Colchester et al., 2007). Even at recent palm oil highs of over US\$1000 per ton, many farmers were not better off (*ibid*). Company owners and investors grew rich, but profits did not pass to growers and pickers. Now that CPO prices have declined,

smallholders are even worse off. Economic studies show farmers would have a more stable cash flow if they grew multiple crops instead of monocrop oil palm. However, Indonesian palm smallholders are tied to 25-year production cycles, and the government offers limited support to develop a greater variety of crops, like rubber, cacao, and pepper.

CONCLUSION

Experience suggests that biodiesel production may lend itself to smaller-scale operations while ethanol from sugarcane and corn is most efficient at large scales. However, specific interventions aimed at supporting smallholders, such as contract farming and technical assistance, are required if smallholders are to benefit. The experience in Malaysia with FELDA and, to a lesser extent, the nucleus-plasma system in Indonesia, demonstrate how government planning can effectively support smallholder participation in the production of commodity agricultural crops that are used to make biofuels.

6.3.3 EMPLOYMENT IMPACTS AND LABOR RIGHTS

Biofuels advocates claim that wide-scale promotion of biofuels will create significant employment and help to bolster livelihood in struggling rural economies in Asia. Biodiesel feedstocks generally have higher labor requirements than grain-based ethanol feedstocks but the number of jobs associated with biofuels production heavily depends on the degree of mechanization. Jatropha is claimed to generate the most number of jobs per hectare because it must be hand-harvested, although other crops can increase employment if production is not highly mechanized. Nevertheless, experience around the world shows that promised levels of job creation from biofuels have not materialized given commercial pressures to increase efficiency. Furthermore, there is ample evidence of workers being exploited, and regulations to protect plantation workers' rights are weak and often unenforced.

EMPLOYMENT POTENTIAL

As biofuels production expands, net job creation is more likely if feedstock production does not displace other agricultural activities or if the displaced activities are less labor-intensive. The impacts will depend on each country's land and labor resources and the type of feedstock

cultivated. Estimates are that sugarcane generates 0.05-0.1 full-time direct jobs per hectare, oil palm generates 0.1-0.2 jobs per hectare, and jatropha generates 0.2-1 jobs per hectare (MIT 2008, de Moraes and Azanha, 2008; Smeets et al., 2006; UNEP/Worldwatch, 2008; MPOC, 2008).

Even within a single country, and for one crop, labor intensity varies substantially. In Brazil, sugarcane production uses three times as much labor in the northeast as it does in the south-central sugarcane heartland (FAO biofuels, 2008), in part because of mechanized harvesting (de Moraes and Azanha, 2008). Increased reliance on mechanical harvesting reduced sugarcane employment from 670,000 in 1992, to 450,000 in 2003. Today, the number of sugarcane field workers may be as low as 300,000 (Worldwatch/UNEP, 2008).

Indonesia is planning a major expansion in oil palm production and, according to the Singapore Institute of International Affairs, projecting some 3.5 million new plantation jobs by 2010. In China, the liquid biofuels program is predicted to create up to 9.26 million jobs (Dufey, 2006). Yet employment estimates on new plantations vary. For example, a 2006 study in West Kalimantan found that some 200,000 hectares of new plantation land employed fewer than 2,000 people, compared with more than 200,000 smallholders who found subsistence and employment on 80,000 hectares of land—almost 260 times the employment potential (Worldwatch/UNEP, 2008). Similar results have been reported from an initiative in India (**Box 11**).

While oilseeds generally provide more employment than grains do because they rely largely on harvesting by hand, these examples suggest the connection between large-scale employment of rural laborers and increased biofuels feedstock production is uncertain. Despite the desire of governments to boost employment through biofuels agricultural activity, the industry tends to pursue economies of scale and vertical integration in order to yield products that are competitive with petroleum fuels.

High labor requirements for biofuels expansion may bring other challenges, namely the process of procuring labor and setting up the necessary infrastructure and logistics to support the workers. For example, Indonesia plans to cultivate jatropha on 1.5 million hectares of land by

Box 11. Fueling Job Creation in India

In India, the National Biodiesel Mission envisioned jatropha cultivation on 400,000 hectares of marginalized lands by 2007, and a further 10 million hectares of wasteland and other idle land adjacent to railway tracks by 2012. Such a massive project, intended to replace 20 percent of India's diesel consumption with biodiesel, is projected to employ between 2.5 and 5 million people. However, only a fraction of the pilot phase acreage has been cultivated to date. The viability of the ambitious employment scheme remains debatable, especially given the unproven nature of jatropha oil as a large-scale biodiesel feedstock.

2010. Based on estimates above, this will require between 375,000 to 1.5 million workers to operate the plantations, many of which are in remote areas with little infrastructure. These locations present challenges for infrastructure and services such as water and sanitation, transport, and healthcare. Also, without an effective human rights regime, the need to procure large numbers of agricultural workers could create a perverse incentive to convert rural communities into forced labor.

LABOR RIGHTS

Plantations, like other large-scale users of unskilled labor, are rife with abuses against workers. In the case of Brazil, for example, the sugarcane industry has historically been marked by exploitation of seasonal laborers, often subjected to working and living in very harsh conditions so appalling as to be labeled slavery. Some workers are trapped in debt bondage, working at least 13 hours a day and living in miserable conditions (Newman, 2008). Despite the Brazilian Ministry of Labor's efforts to rescue bonded or otherwise exploited laborers, international agencies, including Amnesty International, continue to document widespread abuses.

Similarly, plantation workers in Indonesia and Malaysia have few rights. Indonesian migrant workers laboring on Malaysian plantations are particularly vulnerable to predatory practices and forced labor. Regulations and monitoring related to handling toxic agrochemicals are weak or nonexistent. Furthermore, Indonesia's Commission for Child Protection recently accused Malaysia's oil palm planters of enslaving migrant workers and their children at plantations in Sabah in Borneo by holding them in isolated barracks with no access to transportation, clean water, lighting, or other facilities (Maulia, 2008).

While national governments are responsible for safeguarding the rights of plantation workers, importing countries are under pressure to ensure their biofuels purchases are produced according to international standards and do not cause undue harm to the environment or to social welfare. The Roundtable on Sustainable Palm Oil (RSPO)—a collaboration between leading players in the palm oil sector and major conservation organizations—has developed standards so that certified oil palm estates and mills comply with national and international laws, including those concerning labor rights, customary rights, and rights of local/indigenous communities (Colchester et al., 2007).

CONCLUSION

Biofuels production can produce expanded employment opportunities in rural Asia. However, these opportunities are not guaranteed, and occasionally workers are severely exploited. The need to lower production costs of biofuels offers considerable incentives for the wide-scale adoption of new and less labor-intensive technologies. If biofuels are to provide large-scale employment, then achieving a balance between new jobs and mechanization is crucial.

6.3.4 RIGHTS OF INDIGENOUS PEOPLES AND LAND CONFLICTS

The push to produce large amounts of biofuels could increase infringement of land rights traditionally held by local communities and indigenous peoples and lead to a land grab by influential actors acting in concert with local elites. Much of the conflict to date has been in relation to palm oil development, as local people have been either forced off their land without consent or have been convinced to leave based on empty promises. Unfortunately for indigenous peoples, who are heavily

dependent on the lands they have used for centuries, oppression and loss of land rights with little or minimal compensation have been common. Several examples of conflict-ridden situations are profiled below.

PLANTATION AND “IDLE LAND” CONFLICTS

In early 2008, Indonesia reported that 7.3 million hectares of land were being used for oil palm cultivation. A further 18 million hectares of land were cleared but not subsequently planted. Rather than oil palm plantation development, the prime motivation for clearing the additional land was for extraction of timber. Despite this dramatic misuse of plantation land for forest clearing, regional development plans still assign an additional 20 million hectares of land for plantation expansion by 2020, primarily in Sumatra, Kalimantan, Sulawesi, and West Papua. Indigenous peoples have derived livelihoods for generations on most of these lands; an estimated 60 million people in Indonesia rely directly on the forests for their food, medicine, and other products (Marti, 2008).

International and Indonesian law require plantation developers to request free, prior, and informed consent from indigenous people for the development proposals affecting their land—but this rarely takes place. Consultation that does occur is often not open or transparent. Bribery or promises of schools, roads, and irrigation are frequently used so village chiefs agree to the development. The promises often fall short, and communities are left feeling deceived when it becomes apparent that many new jobs are temporary. Moreover, many of the jobs created are for casual day laborers. It is not surprising that the plantation sector is the most conflict-prone in Indonesia. According to Sawit Watch, in 2006 more than 350 communities were involved in land conflicts over the proposed or ongoing expansion of oil palm plantations.

As discussed in Section 6.3.2, several reports have also documented widespread negative impacts involving smallholder schemes (Colchester et al., 2007). Repression and coercion, lack of information, and loss of land rights have accompanied some oil palm production. The nucleus-plasma schemes, for example, not only occupy lands with overlapping systems of customary (adat) ownership, but also disrupt adat arrangements by allocating plasma farmers plots that belong to other communities.

In Malaysia, oil palm plantation companies are also being given rights over supposedly “vacant” or “idle” lands that are obviously inhabited, resulting in local people contesting many oil palm projects. At least 40 communities in Sarawak have taken companies to court to defend their rights, but many lack access to or know-how to seek legal representation (Zen et al., 2006).

Even extension of biofuels agriculture into marginalized lands is not immune to controversy, and there is growing doubt about the very concept of “idle” land. In many cases, lands perceived by government and large private operators to be idle, marginalized, or abandoned actually provide livelihoods for poorer and vulnerable groups through crop farming, herding, foraging, and other means (Dufey et al., 2007). In India, for instance, the widespread planting of *jatropha* on “wasteland” has been brought into question. Among the reasons for this, much of India’s wastelands are classified as common property resources (CPRs), collectively owned by rural groups and villages. CPRs play a vital role in the lives of these groups by supplying commodities like food, fodder, timber, and thatching material. CPRs can contribute between 12 and 25 percent of a poor rural household’s income. Planting *jatropha* on these lands may impose a high opportunity cost on these communities by denying them a source of food, fodder, and small timber.

In southwest China, much of the “barren” land identified by provincial governments for *jatropha* production is owned not by the state but by village collectives, with use rights granted to individual households. In Yunnan, for instance, a recent provincial survey found that the state owns only 24 percent of the forestlands, while collectives own the remaining 76 percent. Most private investment in biofuels has so far been limited to state-owned land, but ambitious targets for scaling up *jatropha* production are likely to encounter problems with land availability and will likely have to extend cultivation to collective lands (Weyerhaeuser et al., 2007).

CONCLUSION

Evidence from across Asia and elsewhere shows that very often, expansion of biofuels production, especially onto non-agricultural lands, could threaten indigenous and marginalized communities. Even so-called idle lands are often the only resource accessible to the landless poor. Converting these lands to biofuels production could deny local communities access to subsistence farming, fuel wood,

Box 12. A Decentralized Biofuels System in Brazil

In southern Brazil, a cooperative of small farmers, with technical support from a German NGO, is setting the standard for sustainable local production of biodiesel. They have tested a small facility that produces cold-pressed vegetable oil for cooking or, after additional filtration, fuel. Vehicles have used the oil for more than 20,000 kilometers without problems. The farmers are not dependent on fuel from a large plant or subject to the control of conventional traders. Cold-pressed oil and its by-products fetch higher prices on the market, providing an additional source of income. By being self-sufficient in producing fuel, the cooperative also avoids a fuel tax that can be as high as 18 percent. This project is supported by the state government of Parana and the Brazilian Ministry for Rural Development.

Source: Prado, 2006

and fodder. This poses a real threat to the social sustainability of biofuels and can precipitate severe conflicts. Greater enforcement is needed to ensure indigenous peoples fully understand and have a voice in plantation development so that they can give informed consent. Where people are displaced, just compensation must be provided.

6.3.5. BIOFUELS FOR DECENTRALIZED ENERGY

Much of the discussion today focuses on the merits and demerits of biofuels as a globally traded alternative to gasoline and diesel used in urban areas. There has been little focus on the potential for biofuels to increase access to energy in Asia's rural settings. Many poor communities in Asia have limited or no access to grid-connected electricity—for example, roughly 44 percent in India and 48 percent in rural Indonesia—or affordable transport fuels (Nouni et al., 2008; World Bank, 2005). These households rely on traditional biomass, or expensive fossil fuels for running generators or for lighting and cooking. Biofuels can play an important role in decentralized energy production, while building and revitalizing rural communities through integrated, community-

supported agriculture and energy services. The following examples show how decentralized biofuels production can be a cost-effective and successful way to provide electricity and liquid fuels—even in the most remote areas—to potentially large numbers of people currently lacking access to these services. The main challenge is to get decentralized biofuels on the agenda of policy-makers, who tend to be focused on large-scale solutions.

MODELS FOR SMALL-SCALE BIOFUELS PRODUCTION AND DEVELOPMENT

In a decentralized system, most commonly available biofuels include straight vegetable oil (SVO), also known as pure plant oil, or transesterified oil produced from feedstock such as rapeseed, sunflower, palm, coconut, jatropha, or waste oil. Local producers grow feedstock on marginalized lands, homesteads, or common property. The local equipment used to process the feedstock and generate power typically comprises a seed crusher, expeller and oil extraction unit, generator, and battery charger or a mini-grid system. Non-governmental organizations (NGOs) and government agencies often help communities with

Box 13. Rural Electrification Powered by Jatropha in Mali

Since 1999, the Mali Folk Center Nyetaa—a local NGO with support from Denmark's Folk Center for Renewable Energy and several UN agencies—has promoted jatropha cultivation for bioenergy. In the village of Tiecourabougou, this group fostered development of 20 hectares of land to produce oil to power activities such as grinding millet and charging batteries. Villages in a 20-kilometer radius benefit. In southern Mali, the NGO will grow jatropha on 1000 hectares for a 300-kilowatt power plant, aiming to provide electricity to more than 10,000 residents.

Source: UN-Energy, 2007

initial funding to purchase machinery and with technical assistance, as well as formation of cooperatives to grow or procure resources. One model for small-scale biofuels consumption involves powering local transportation (**Box 12**). Doing so especially benefits rural populations where distribution of conventional fossil fuels is limited and often costly—isolated areas in India and the remote smaller islands of Indonesia are prime examples. Small-scale biofuels systems create a steady supply of fuel and protect users from crippling price fluctuations.

Decentralized biofuels initiatives can also provide household energy services to underprivileged rural communities (**Box 13**). In a simple yet striking illustration, Rajagopal (2007) calculated the amount of land needed to produce enough oil to generate electricity (using diesel generators) for an Indian village of 100 households. Extrapolating this number, he found the amount of land required to supply 100 watts of electricity for eight hours per day to all 90 million rural, previously un-electrified households in India is less than the amount of land required to meet India's 20 percent target for transport biodiesel. While 100 watts is only a small amount, the exercise underlines an important question: What is the best manner in which to allocate energy produced from biofuels feedstocks? Biofuels may be produced more sustainably on a community-based scale

with a greater impact on the welfare of populations if dedicated to household consumption rather than transport (**Box 14**).

Clearly, more detailed analysis is needed to compare the use of biofuels for transport to rural household use, but preliminary indications suggest that decentralized fuel and electricity generation in Asia is a viable alternative to relying on commercial production to meet nationally established blending mandates.

CHALLENGES TO DECENTRALIZED SMALL-SCALE BIOFUELS PRODUCTION

Several challenges impede widespread promotion of decentralized biofuels systems. The original motives behind development of biofuels for transport—reducing GHG emissions and energy dependence—became hot-button issues for governments and international agencies. The rising cost of fossil fuels over the last several years has elevated the attention of investors and large corporations. The use of biofuels for decentralized rural electrification, on the other hand, is neither lucrative nor particularly topical. It is unlikely to attract the same degree of attention or sustained funding efforts. Realistically, such initiatives will remain the focus of NGOs and local governments, which will be able to fund and monitor a

Box 14. A Micro-Grid Using Biofuels in Rural India

In 2004, USAID funded and initiated a rural energy project that sought to improve natural resources management and minimize GHG emissions. In the remote village of Chalpadi in Andhra Pradesh, oil extracted from the seeds of *Pongamia pinnata* trees is used to produce electricity. The local government jump-started the project by providing \$8,000 for hardware (a diesel genset engine, wiring, etc.) to establish a micro-grid that generates and distributes electricity throughout the village. The villagers provide the oil fuel to operate the genset, and operate and maintain the system. To ensure long-term viability, the village developed a method of self-governance that regulates fueling and operation of the system, and who has access to the electricity. The families pay one kilogram of pongamia seeds per day to access the micro-grid. By asking families to pay in pongamia seeds, it encourages ownership in the system and ensures there is adequate feedstock to use in the biodiesel generator.

The benefits of the system include electricity for household use and a new agricultural/forest crop of value. Cultivation of pongamia in hedgerows, windbreaks, and nonproductive areas also reduces soil erosion, increases soil fertility, improves wildlife habitat, and provides other natural resource benefits. Following the successful startup and operation of the village scheme, in 2003 Chalpadi became an environmental pioneer by selling 900 tons of CO_{2e} verified emission reductions to Germany. The carbon sale fetched the community \$4,164—which is equivalent to several months of income for every family in the village.

Source: EGAT, 2004

Box 15. Productivity Increases in Brazil

Brazil now has the lowest production costs in the world for ethanol from sugarcane. Brazil has been able to increase productivity by raising yields and introducing more efficient supply chain logistics. Since 1975, agricultural output has increased by 33 percent, efficiency in converting sucrose to ethanol by 14 percent, productivity of the fermentation process by 130 percent, and sucrose content in sugarcane by more than 8 percent (Macedo and Nogueira, 2004). Ethanol productivity from one hectare of sugarcane rose from 2,024 to 5,500 liters. The EIA estimates that the costs of Brazilian sugarcane ethanol could be as low as US\$0.20 per liter of gasoline equivalent by 2030 (EIA, 2006). This will be achieved through the development of co-products to be used as value-added outputs and a reduction in input costs through the use of process energy (e.g., by co-firing with sugarcane bagasse).

limited number of micro-projects and provide subsidies that encourage feedstock cultivation.

Local energy development initiatives using biofuels also encounter technical obstacles. Owing to their small scale, decentralized systems do not reach the conversion efficiency levels achieved by larger-scale operations. While SVO can be used in a range of engines, engine wear and tear and maintenance requirements may end up being high relative to diesel. In one study in Thailand (Prateepchaikul and Apichato, 2003), diesel engines ran continuously for 2,000 hours using both regular petro-diesel and refined palm oil. The authors found little difference in engine wear or smoke emissions between the two fuels, suggesting refined palm oil as a suitable diesel surrogate, although the test used refined palm oil, not crude palm oil. Other studies have shown that blends with more than 20 percent SVO often result in engine damage or maintenance problems in the long run (Jones and Peterson, 2002). The high viscosity of unrefined vegetable oils presents difficulties in a combustion chamber. Most of these findings came from testing conventional vegetable oils like rapeseed and palm. Preliminary field reports indicate the chemical and physical characteristics of oils from pongamia and jatropha may be more suitable as SVO fuels.

CONCLUSION

As the case studies indicate, biofuels could play a significant role in expanding access to energy for the rural poor through community-based initiatives to produce biofuels and generate power for household use. To effectively scale up decentralized schemes it will be necessary to overcome the dominant preferences of policymakers and investors, who are focused on large-scale biofuels

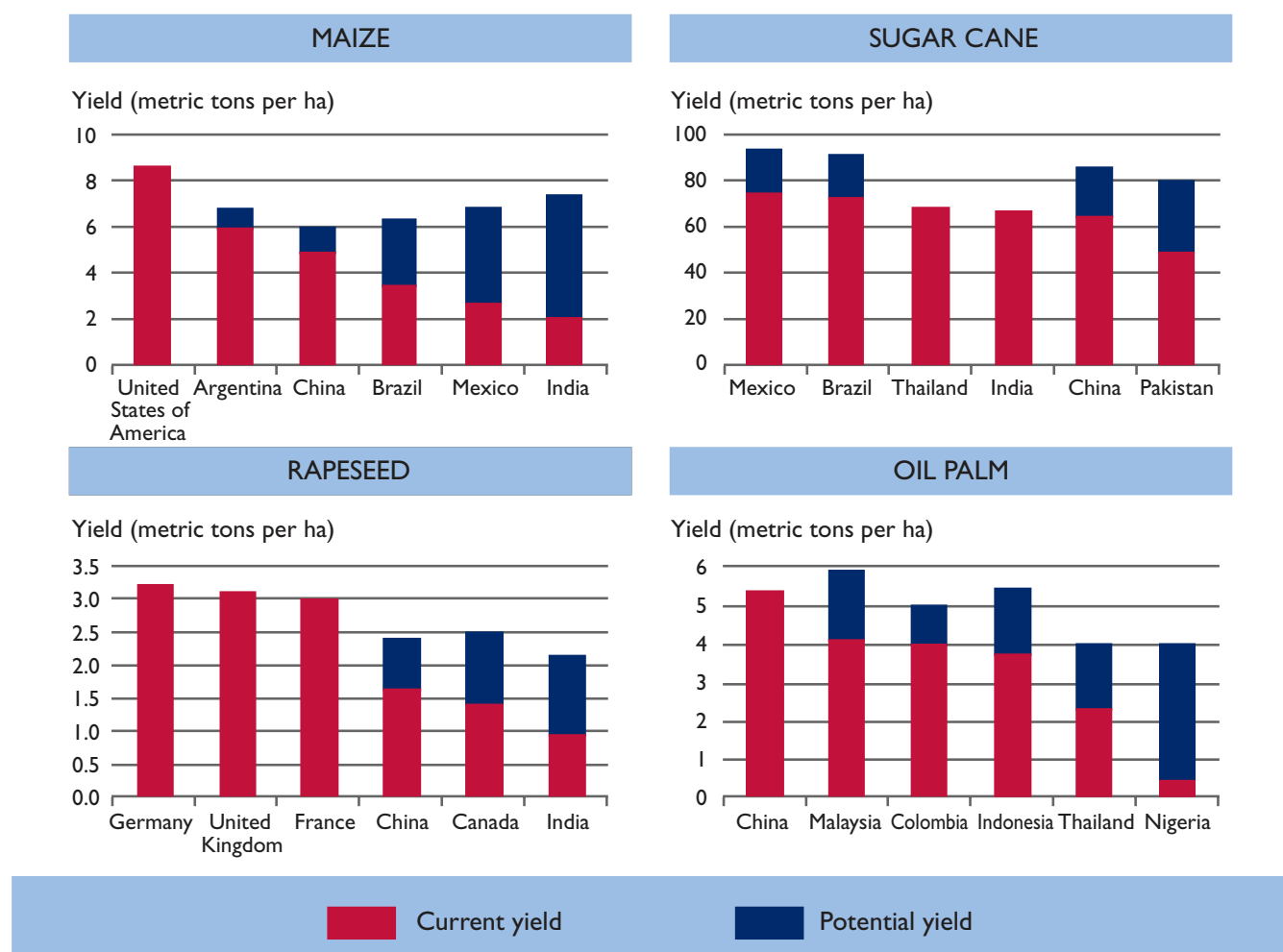
systems meant to produce liquid biofuels for the national transportation sector. Additionally, technical challenges relating to use of SVOs in generators and engines will need to be addressed.

6.4 TECHNOLOGY CHALLENGES

Biofuels deployment depends on proven, cost-effective technologies. While first-generation technologies are mature, they can benefit from increased yields and process efficiencies and lower costs. Second- and third-generation systems will need to overcome many challenges before they become commercial. As R&D advances production technologies and supply logistics, costs will drop. This section identifies the key technology challenges that affect biofuels development at all stages. Across all three generations of biofuels, the ability to reduce costs depends heavily on improvements to logistics along the value chain and the introduction of integrated processes that create a variety of products to strengthen financial resilience.

FIRST-GENERATION BIOFUELS

Improvements in first-generation biofuels technologies are expected to continue, although they will likely be insufficient to erase concerns over their impacts on the environment and food markets. The exception will probably be ethanol from sugarcane. In the near term, industrial productivity is projected to increase from 80 to 90 liters of ethanol per ton of sugarcane with no increase in production cost (Macedo and Nogueira, 2004). Progress is also expected in other areas of the sugarcane-to-ethanol pathway. Overall, production costs are projected to fall to US\$0.30 per liter in the United States by 2030 and even less in Brazil (**Box 15**) (IEA, 2006).

FIGURE 22. Potential for Yield Increase for Various Biofuels Feedstocks.

Source: FAO, 2008

Note: In some countries, current yields exceed potential yields as a result of irrigation, multiple cropping, input use, and various other production practices.

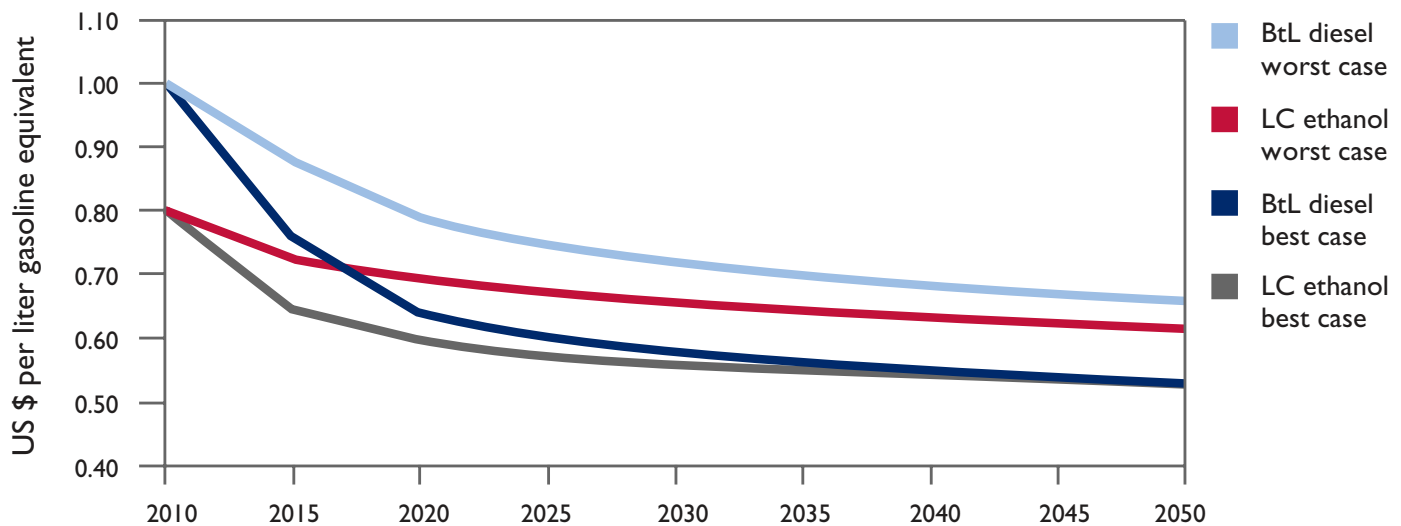
In general, technology improvements for other first-generation crops are possible along the production chain: yields, harvesting, storage, transport, fuel preparation, and processing. Process technologies could also benefit from improvements in dealing with variable quantities and qualities of biomass feedstocks. Cost reductions may also come from increases in plant sizes. Intensifying production—through improved use of fertilizers and other agricultural best practices—on existing areas could play a significant role in meeting increased demand for biofuels in the coming years. Despite significant gains in crop yields in many regions and globally, yields continue to lag in several developing countries (**Figure 22**), suggesting that considerable scope remains for increased production on existing lands. By 2017, crop breeding and agronomic

developments are expected to increase yields in corn by 149-173 bushels per acre, sugarcane by 20-25 tons per acre, and soybeans by 43-46 bushels per acre.

SECOND-GENERATION BIOFUELS

The competitiveness of lignocellulosic biofuels will depend on a number of factors, including development of new enzymes, cost of biomass, and new policies, particularly those related to GHG emissions. Major technology challenges remain for economically viable production via biochemical pathways.

Research areas include reducing the cost of enzymatic saccharification, augmenting the content of cellulose in biomass, and increasing the digestibility of cellulose prior

FIGURE 23. Projected Cost Ranges for Second Generation Biofuels to 2050

Source: IEA, 2008a

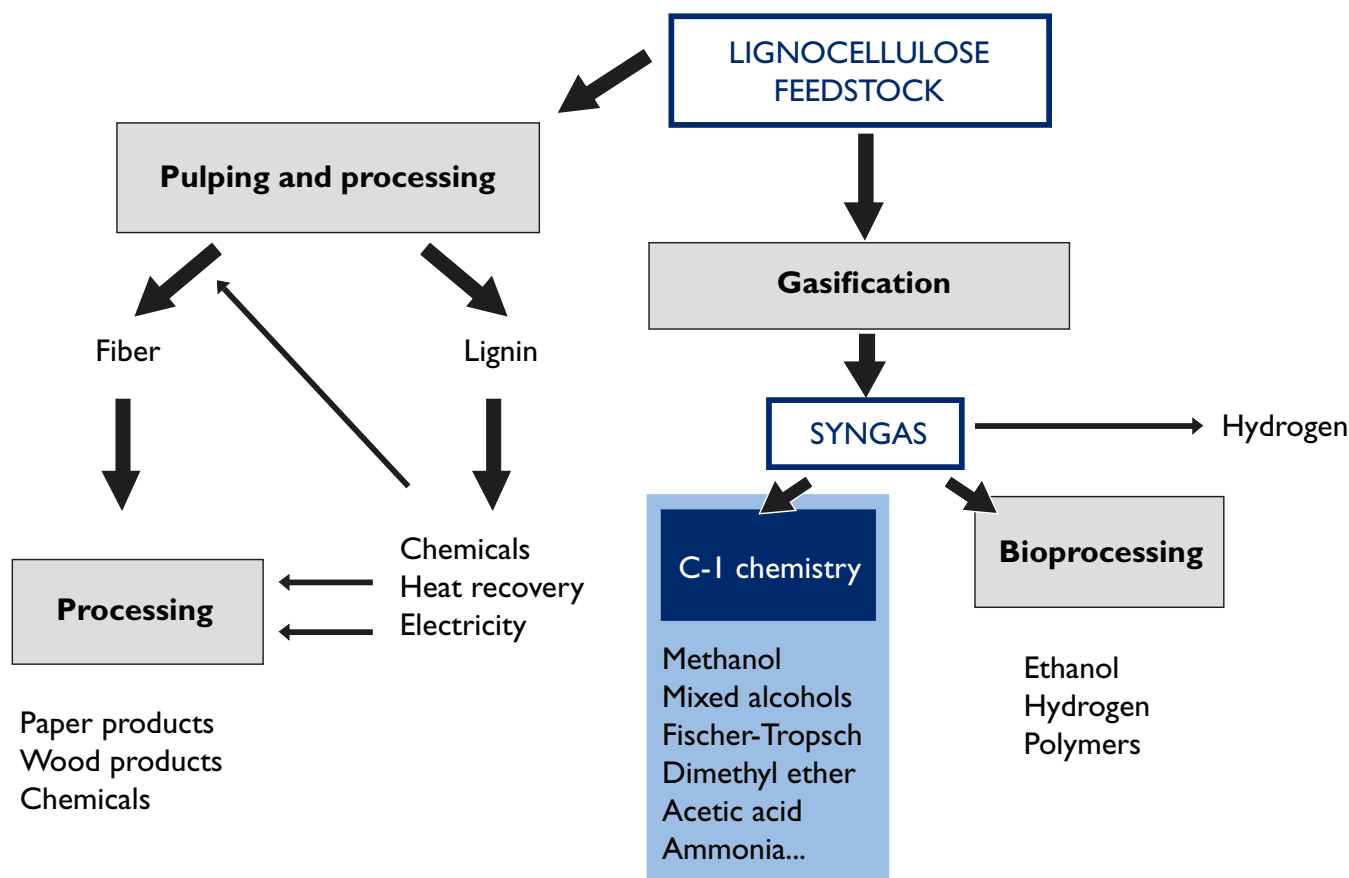
to enzymatic treatment. Research is underway to use cellulosic residues of sugarcane (bagasse) to produce additional ethanol via hydrolysis. A reported 100 liters of ethanol can be produced from bagasse with current technology, and an 80 percent increase in productivity is expected with new technologies. Significant investment in second-generation biofuels R&D by the US Department of Energy has resulted in a 10-fold reduction in production costs in recent years. Under an optimistic scenario of technological advances, it is projected that the cost of producing one liter of cellulosic bagasse ethanol could go from the current costs of US\$0.80-\$1 per liter to US\$0.55-\$0.65 per liter by 2050 (**Figure 23**). However, these costs are not expected to be competitive with the current cost of sugarcane ethanol. The United States has built prototype plants with estimated cellulosic ethanol production costs of US\$1 per liter of gasoline equivalent. The viability of the bagasse-to-ethanol will rely on the ability to integrate it into conventional processes, which could result in a 30 percent increase in productivity.

Cost reductions are also projected for thermochemical biofuels production via gasification. Elements of gasification technologies have been around for decades, but R&D is needed to establish a complete, integrated technological platform. Current costs of Fischer-Tropsch (also known as biomass-to-liquids or BtL) diesel are above US\$1.00 per

liter, though long-term costs of US\$0.55 to 0.70 per liter are expected (**Figure 23**).

THE BIOREFINERY CONCEPT

To date, the use of sugar- and oil-rich crops as well as biomass has been directed at producing refined transport fuel, although technologies are emerging to use biomass inputs to manufacture a variety of fuels, chemicals, and plastics. The incorporation of multiple products and end-uses has culminated in the integrated refinery process known as a biorefinery. The biorefinery process neatly conceptualizes the most promising pathway to developing a bio-based economy. It would integrate a series of biomass production processes and equipment to produce fuels and chemicals, and to generate electricity. As shown in **Figure 24**, biomass is fed into the refinery. It is treated biochemically to produce sugars and thermochemically to produce a synthetic gas, which in turn are used to produce fuels and chemicals via different processes. Simultaneously, residual biomass from the biochemical process and residual gases from the thermochemical process are used in the combined heat and power platform to generate electricity and heat. The following figure illustrates possible end-products, including pulp recovery for paper, gasification for gaseous fuel, and biological processing for bioethanol, along with hydrogen fuel and polymers for plastics.

FIGURE 24. The Biorefinery Process

Source: Taylor, 2008

THIRD-GENERATION BIOFUELS

The primary challenge for producing biofuels from algae is to bring its extremely high costs into the competitive range. Making algae biodiesel economically competitive will require additional research and development in genetic and metabolic engineering to produce higher yielding and hardier strains. Photo bioreactors that generate high yields at reasonable capital costs also need to be developed, since economies of scale could be significant for algae-to-biodiesel facilities. Two leading challenges lie in finding ways to incorporate wastewater treatment and the utilization of carbon dioxide from power plants into large-scale production facilities. In one study, the US National Renewable Energy Laboratory (NREL) reports that if some key technology challenges are resolved, some 7.5 billion gallons of biodiesel could be produced from algae using 200,000 hectares of desert land—avoiding the need for land conversion or use of ecologically sensitive land (Briggs, 2004).



PHOTO COURTESY PRADEEP THARAKAN

Developing and Testing Algae Strains at a Facility in Malaysia.

SECTION 7

POLICY GUIDELINES FOR SUSTAINABLE BIOFUELS IN ASIA

It is clear from the preceding discussion that biofuels have the potential to address climate-change mitigation, energy security, and agricultural development, but they also entail significant risks in terms of economic, environmental, and social impacts. Key operating assumptions regarding the current and potential value of biofuels need re-evaluation. Prudent policies are crucial to enable development of sustainable biofuels while limiting the risks. This section provides a set of guidelines for designing policies that could support a sustainable biofuels sector in Asia, keeping in mind these principles:

- protect the poor and bolster their access to adequate food and energy supplies;
- ensure that production and utilization of biofuels are environmentally sustainable, lead to greenhouse gas reductions, and do not negatively impact land, water, or air resources;
- follow a market-oriented approach that reduces distortions in agricultural markets, ineffective and expensive subsidies, and considers long-term impacts, as well as social costs and benefits;

- improve regional and international coordination to ensure harmonized definitions, standards, measurement approaches, and sustainability goals while accommodating domestic agricultural development and poverty reduction priorities; and
- recognize that liquid biofuels are one among a suite of options available to promote clean transport, including energy efficiency, improved mass transport, and electric vehicles.

7.1 FACILITATING ENVIRONMENTALLY SUSTAINABLE BIOFUELS PRODUCTION

COMPETITION FOR LAND RESOURCES

Converting forestlands, grasslands, and shrub lands to accommodate increasing demand for biofuels will have adverse effects on ecosystem services, and converting food-producing land could threaten food security. The use of abandoned agricultural or underutilized lands could avoid these problems (**Box 16**). As shown in **Section 5**, after excluding forestland, protected areas, and land for food and feed, adequate land does exist to support increased

Box 16. Yield Increases and Expansion on Underutilized Lands for Oil Palm in Indonesia

A recent study found that by focusing first on improving yields of existing oil palm plantations in Indonesia, and followed by expansion on underutilized grasslands and degraded forests, the industry can meet the growing demand for palm oil, be financially viable, minimize impacts to biodiversity, meet climate change criteria in terms of carbon payback times, and avoid deforestation. The study concludes that a 35 percent increase in yield is not unrealistic. This increase in yields translates into 1.6 million hectares of oil palm plantations avoided. Regarding potential expansion, the study found that oil palm produced the highest economic returns when planted on degraded land, followed by flat secondary forest or grassland. Hilly land gave poor economic returns because of the cost of terracing steep slopes and heath soils require costly break-up of the underlying dense soil layer. There is broad agreement that oil palm, when planted on grasslands or woody savannah will achieve carbon payback well within one planting cycle of about 25 years. For plantation companies, executing best management practices and addressing nutritional deficiencies in a timely matter has a much greater and more rapid financial payback than expanding the area planted.

Source: Fairhurst and McLaughlin, 2009

production of first-generation biofuels to meet the focus countries' mandates and targets, with some caveats.

Much of the information on available or unutilized land is of very poor quality—most data are only available at a coarse level on national or sub-national scales. There is also very little explicit spatial information to indicate: how much of this land is free from competing uses; the quality of the land and level of biomass production it could sustainably support; and access to water, infrastructure, and end-use centers. Such details would allow more accurate assessments of the potential of these lands to support viable biofuels feedstock production. It is likely that the extent of available land is much lower than what the countries themselves have projected.¹

As noted in **Section 6.3.4**, underutilized land provides a range of ecosystem and social services for the rural poor and marginalized communities—including seasonal grazing, subsistence farming, fodder, and small timber. In opening up these lands for biofuels production, care should be taken to ensure that these people are not forced off the land and that their needs—for which there are no alternate sources—are reconciled with the interest in biofuels production. In addition, the economic imperative to maximize revenue suggests that growers will continue to prefer richer croplands to produce more biofuels for the same effort. This would encourage the migration of production to forestlands and croplands from abandoned land, leading to increased deforestation and pressure on food supply. Policy measures and strict enforcement of operating guidelines would be needed to ensure that such leakages and other unintended consequences do not occur. Further, the use of residues in cellulosic ethanol production systems—due to their higher fuel yields—could lower the overall land requirements.

IMPACTS ON SOIL QUALITY

As detailed in **Section 6.1.6**, expanding biofuels production can damage soils, but these impacts—similar to agriculture—are dependent on crop type, management practices, intensity of inputs, and harvesting strategy. Improved management practices, such as conservation tillage, crop rotation, retention of crop residues, and improved fertilization application techniques, can help

reduce adverse impacts while improving yields of first-generation annual crops. The focus should be on crops with lower fertilization demand, and within a crop, on cultivars or varieties with higher nutrient-use efficiencies.

Perennials, such as oil palm, and dedicated energy crops, such as jatropha, short-rotation woody crops, and grasses, require less intensive management and lower amounts of agro-chemicals. When planted on degraded lands, they have lower soil erosion rates and increased soil carbon levels. Where possible, mixtures of native perennials (inter-cropping) should be used since they provide the greatest benefits in terms of high biomass gain and low requirements for fertilizers.

The use of agricultural residues as feedstock for cellulosic ethanol is associated with significant risks for maintenance of soil quality—especially soil organic carbon—and needs to be managed carefully. Typically, only 25–33 percent of crop residues can be harvested sustainably. Guidelines for sustainable levels of residue off-take for combinations of soil types and crops need to be developed, and growers and biofuels processors should be required to adhere to these guidelines.

IMPACTS ON WATER AVAILABILITY AND QUALITY

Most studies have concluded that water withdrawals to support an expanded biofuels production level in 2030 do not pose a significant risk to overall global water availability. However, in India and China, where water is already scarce, growing feedstocks for biofuels—especially food-based crops such as maize and sugarcane on a large scale—will result in severe competition for remaining resources. Even regions that do not suffer from water scarcity may experience local shortages. Expanding biofuels production is contingent on society rethinking the way it uses water for agriculture (IWMI, 2007). Simply expanding irrigation to realize higher yields is not an option in many parts of the world.

Water use for biofuels production should be predicated on: (1) increasing productivity of water to get more yield per unit of water by managing soil fertility; (2) using water efficient crops; (3) minimizing irrigation water waste and increasing conversion efficiencies; (4) upgrading rain-fed

¹ See Annex 5 for the Indonesian government's estimates of land available for biofuels crops. Note that much of the land considered "available" is either used by indigenous peoples or is high conservation value habitat (e.g., central Borneo). Furthermore, much of it is remote, requiring substantial infrastructure development.

systems by improving soil moisture retention, and (5) strengthening ecosystem services by lowering pollution impacts and supporting biodiversity and multiple-use contexts. Fertilizer demands can be reduced through: (1) the use of non-food crops with lower nutrient demand; (2) choosing species varieties with higher nutrient-use efficiency and therefore lower nutrient demand; (3) improving nitrogen application efficiency; and (4) returning processed feedstock back to the field.

IMPACTS ON BIODIVERSITY

To date, most of the impacts of biofuels on biodiversity have been negative. To safeguard remaining biodiversity, it is imperative that forests not be converted to biofuels. Future increases in production should be based on intensification of production on existing lands and establishment of plantations on degraded lands where indigenous vegetation is not expected to regenerate. To ensure compliance, all large-scale biofuels schemes should be subject to detailed environmental audits and impact assessments. Given that oil palm and other biofuels crops are ideally suited for tropical Asia, economic pressures for continued forest conversion will likely persist. Adoption of systems that support payments for environment services would help provide an economic incentive for preserving the remaining forests in Southeast Asia (**Box 18**).

Safeguards have been developed for cases where plantations need to be close to forest areas or involve unavoidable forest conversion. Maintaining tracts of natural habitat within or in the vicinity of new plantations will help safeguard a modest level of biodiversity. In Brazil, for example, environmental regulations now require that 25 percent of new plantation areas be left as natural vegetation to help preserve biodiversity. Also, forest products companies have found natural areas support predators that help control pest populations in nearby plantation stands. Similarly, plantations can be leveraged to enhance biodiversity when the crops fill gaps between remaining fragments of natural habitat and are managed so that biological corridors remain, allowing animals to travel between larger habitat areas.

Divorcing biofuels production from monoculture may prove difficult without strong government incentives for crop rotation and intercropping. As smallholders are more likely to adopt intercropping techniques for subsistence and

additional income, encouraging agricultural biodiversity is connected with smallholder participation in biofuels.

Switching from annual crops to perennial energy crops (e.g., woody species, grasses) has a positive impact on biodiversity (e.g., Tharakan et al, 2006). Deploying them in polycultures interspersed with unmanaged habitats increases crop biodiversity on-site while providing for wildlife corridors and other conditions that support biodiversity. Experimental data show that native species capitalize on low-input conditions and tolerate stress better than exotics and should be deployed where possible (Tilman, Hill, and Lehman, 2006). Some feedstocks promoted as second-generation biofuels are classified as invasive species, raising new concerns on how to manage their introduction and avoid unintended consequences.

MANAGING GREENHOUSE GAS EMISSIONS

The carbon debt analysis presented in Section 6.1.2 reveals that definitive GHG-benefits from the production of first-generation biofuels are limited to existing croplands and to a lower extent on degraded land. Under no circumstances can conversion of peatlands or primary or secondary forests be justified from a GHG perspective. On most other lands, the possibility of achieving a positive GHG balance during the crucial next few decades depends on the particular site characteristics and biofuel. Within existing processes, the GHG footprint can be improved substantially through best management practices. For example, in the case of oil palm plantations, these include well-controlled anaerobic digestion of aqueous wastes, use of methane from palm oil processing (Reijnders and Huijbregts, 2008; Yapp et al., 2008). Other best practices include utilization of cover crops to maintain soil moisture and prevent erosion, prevention of fires, reduced use of fertilizers, and maintenance of a high water table.

Second-generation biofuels from feedstocks such as *jatropha*, fast-growing woody species, and grasses may lower carbon debts and payback times, especially in low-input systems on degraded lands. The excessive use of irrigation and fertilizers tends to lower the overall GHG benefits. Cellulosic ethanol may also increase the GHG balance of some first-generation biofuels. For example, oil palm accounts for only about 10 percent of total dry biomass produced by oil palms; the remaining 90 percent represents a potential source for cellulose-based ethanol

Box 17. Betting on REDD

A potential Kyoto Protocol-related mechanism that may help reduce deforestation rates and carbon emissions as well as lead to better governance is Reducing Emissions from Deforestation and Forest Degradation (REDD). The program is still in the discussion phase but proposes that wealthy nations reward developing countries with carbon credit payments for protecting tropical and other forests. According to one estimate, the rough value of Indonesia's peat swamps could be worth US\$39 billion in carbon credits annually, given an average carbon offset value of €5 per ton of carbon (Bloomberg, 2007). If REDD enters into force, carbon offset payments made to developing countries in Asia could be worth billions of dollars and could have a significant impact on deforestation rates.

However, there are many challenges, both technical and political, to a REDD program that would effectively reduce emissions from deforestation and degradation of forests. Climate negotiators have not yet agreed on guidelines that resolve issues with permanence (how to ensure forest preserved today are not destroyed tomorrow), leakage (forests saved in one location result in forest destruction in another unprotected location) and monitoring, reporting, and verification (how to measure and verify real GHG reductions). As a way of kick-starting the learning process for REDD, in 2008, 14 countries were selected by the World Bank's Forest Carbon Partnership Facility to receive funds for conserving their tropical forests; three of these countries were in Asia including Nepal, Lao PDR and Vietnam (World Bank, 2008). The general consensus appears to be that REDD can and should be included in future climate change mechanisms, but guidelines and methodologies for REDD have yet to be finalized.

(Basiron, 2007). Still, it is uncertain how much will be available for biofuels production, given that oil palm residues already power the oil palm production process, with the remainder often returned as mulch to plantation soils.

Life cycle assessments (LCAs) offer a framework to evaluate the GHG impact of producing and utilizing biofuels. A number of different methods and operating assumptions are used to conduct these studies—limiting their use in decision-making—and most do not consider the complex yet critical topic of land-use change. Efforts are underway within the Global Bioenergy Partnership (www.globalbioenergy.org) and others to develop a harmonized methodology for assessing GHG balances.

There is a similar need to harmonize assessments of other environmental and social impacts of bioenergy crops to ensure that results are transparent and consistent across systems. Such information, linked with certification systems, would help ensure that biofuels are produced in ways that do not result in unacceptable carbon release. Opportunities for ecosystem services payments to developing countries, such as REDD (**Box 17**), could be an important financial incentive to prevent deforestation and carbon release.

7.2 SUPPORTING SMART ECONOMIC POLICY

FINANCIAL INCENTIVES, SUBSIDIES, AND NATIONAL MANDATES

The production and use of biofuels is dependent upon public funding and support measures, even at oil prices around US\$100 per barrel (OECD, 2008b). OECD countries provide significant support, including mandates and subsidies, and import tariffs that restrict market access by developing countries. These are stacked on top of existing subsidies and protections offered to the agricultural sectors in these countries. The report *Economic Assessment of Biofuels Support Policies* finds government support for biofuels in OECD countries is unjustifiably “costly, has a limited impact on reducing greenhouse gases and improving energy security, and has a significant impact on world crop prices” (OECD, 2008b), with total government support in the US, Canada, and the EU estimated at US\$11 billion in 2006.

Subsidies and mandates can create unnaturally rapid growth in the biofuels industry exacerbating pressure on food prices and natural resources. Political economy lessons suggest that even when subsidies are justified to boost

a nascent industry and designed as temporary, they are often difficult to revoke. It would be more cost-effective to deploy economy-wide or sector-specific carbon taxes or tradable permit systems, which would provide the most efficient policy mechanisms to reduce emissions and potentially shift most first-generation biofuels production away from temperate climates. Brazil provides a successful model in phasing out ethanol subsidies, although it was nearly three decades before its ethanol production system could be said to be self-sustaining without direct subsidies (**Box 18**).

Many Asian countries have followed the lead of the OECD and have employed a combination of mandates, direct subsidies, fuel excise tax credits, and tax holidays to promote biofuels. Subsidy payments and tax exemptions are slated to become more costly as production rises (**Box 19**). There is an urgent need to review these policies

Box 18. The Brazilian Alcohol Program

Brazil's PROALCOOL program, started in 1972, is the world's second largest after the United States and shows how government support can guide the biofuels industry to a subsidy-free and economically sustainable state. Initial subsidies and low-interest loans to bioethanol producers propelled the program that produced 18 billion liters of ethanol in 2007, a 30-fold increase in production. The government also ensured that the resale price of ethanol was below that of gasoline. Today, close to 80 percent of ethanol production is for the domestic market, with roughly 45 percent of vehicles running on minimum blends of 25 percent ethanol. Ninety percent of new vehicle sales are flex-fuel. There are no longer any direct production subsidies for ethanol but the industry benefits from an ethanol mandate and tax reductions, as well as financing for stockholding during the inter-harvest periods. Brazil's success is due in large part to government-backed investments in R&D. Improving yields and conversion processes, developing high energy content species of sugarcane, and improving management practices have helped make Brazil's ethanol industry the lowest-cost and most efficient biofuels production system in the world.

Box 19. Malaysian Support for Biofuels

Malaysia has been pragmatic in its support to the biodiesel industry. Support is confined to soft loans, technology transfer, technical assistance to demonstration plants, and some tax incentives to motivate private investment in the industry. However, the government is planning a national biodiesel mandate that could incur costs greater than would be required to supply the same amount of petroleum diesel—raising questions about whether the new mandates will be cost-effective.

Source: GSI, 2008c

in the light of emerging evidence about the impacts of biofuels. Asian policymakers need to evaluate their blueprints for biofuels development, focusing on the opportunity costs of biofuels policies, land use patterns, and the cost difference between biofuels and fossil fuels. Providing extensive support to current production systems while ignoring more efficient next-generation technologies could lock-in inefficient, unsustainable practices.

Various entities have called for abolishing blending mandates and direct subsidies tied to production and consumption, which would reduce market distortions and minimize some of the negative implications of biofuels. To encourage sustainable biofuels, governments should first end subsidies and price ceilings for fossil-based fuels. Instead of direct subsidies, a more prudent and cost-effective approach would favor capital grants, low-interest or guaranteed loans, demonstration projects, and funding for research and development, targeted specifically at sustainable production of biofuels. As technology develops, a larger share of demand could be met through sustainable yield increases rather than simply expanding cultivated area. Since the energy security and GHG-mitigation potential of biofuels is lower than presumed, it is crucial that Asian policymakers treat biofuels as only one among a range of alternative clean transport strategies including vehicular fuel efficiency, improved mass transport, and electric vehicles. Promotion of biofuels over other options could be counterproductive.

TRADE POLICIES

Political economy, more than economic logic, drives trade policies. Energy and agricultural markets are often greatly distorted, and this situation is unlikely to change soon. Import tariffs on raw materials aimed at protecting domestic production impose an implicit tax on biofuels by raising input prices. Tariffs applied directly to refined biofuels imports distort the market and limit potential for more competitive foreign suppliers. First and foremost, countries must ensure adequate food supply and that their poor are not being exploited. Trade policies can enhance or obstruct the development of environmentally sustainable biofuels. Trade barriers that protect inefficient industries and lax standards can severely undermine environmental objectives.

Biofuels are not yet on the World Trade Organization (WTO) agenda, but Asian countries may want to develop regional trade agreements to avoid the preferential markets of, for example, the EU. International guidelines and multilateral agreements could help developed countries meet their mandates with sustainable supplies from developing countries. If trade barriers are dismantled and quality and sustainability certification systems are in place, biofuels will more effectively contribute to environmental goals, and the market will function more efficiently. Reducing barriers—while building systems for certification and fuel standard harmonization—are vital to future trade (**Section 7.6**). It does not necessarily matter where biofuels are produced or used so long as they make the most effective and efficient contribution possible to reducing GHG emissions (OECD, 2008b).

REGIONAL-LEVEL POLICY RESEARCH AND DEVELOPMENT

A number of regional cross-cutting initiatives are underway to assess the impacts and potential for biofuels in Asia. These initiatives will be important in crafting well-informed policies and harmonizing biofuels activities across the region. The APEC Biofuels Task Force is undertaking biofuels assessments, in particular, an assessment of resource potential on marginalized lands (www.biofuels.apec.org). Ongoing work is focusing on sustainable biofuels development practices, employment opportunities, and

economic feasibility assessments. The Institute for Global Environmental Strategies (IGES) is conducting a three-year study to develop policy recommendations on how to develop biofuels in Asia in line with environmental protection and poverty reduction (<http://www.iges.or.jp/en/bf/outline.html>). This work includes identifying the advantages and disadvantages of biofuels, an assessment of current policies, and an assessment of the social and economic impacts of biofuels trade.

The Asian Development Bank (ADB), under the Rural Renewable Energy Initiative is supporting the Biofuels Development Initiative in the Greater Mekong Subregion (GMS) which aims to assess the viability of developing biofuels in the subregion (ADB, 2009).² It has conducted regional and national-level biofuels assessment and feasibility studies with the aim to develop a sub-regional biofuels development strategy and framework.

The Global Bioenergy Partnership (GBEP), in which the US government is a leading partner, organizes, targets, and implements international research, development, and demonstration related to the use of biomass for energy, aimed at developing countries. The program of work includes formulating a harmonized approach on GHG emissions reductions from the use of biofuels for transportation. Additionally GBEP facilitates collaboration on sustainable bioenergy projects and disseminates information on bioenergy (www.globalbioenergy.org).

These initiatives represent the most significant regional-level efforts to assess biofuels potential and to help steer development and investment in ways that promote sustainability and help reduce poverty.

7.3 ENSURING SOCIAL SUSTAINABILITY

AVOIDING CONFLICTS BETWEEN FOOD AND FUEL

Since peaking in mid-2008, food prices have fallen rapidly. Notwithstanding this dampening of prices, many factors—from population growth to dietary changes in emerging economies—will contribute to increased global demand for

2 The Biofuels Development Initiative includes a characterization of the market outlook and the resource base, a prioritization of feedstocks, assessments of impacts to smallholders, and identification of policy and institutional support for sustainable biofuels development in the GMS. The study recommends developing country-level resource databases, market and research studies, and technology transfer opportunities, particularly for small farmers, to enhance a sub-regional strategic biofuels framework. Full results of the assessment study and country-level analysis will be published by June 2009.

food in the next two decades and put an upward pressure on prices. The current thrust to produce biofuels from first-generation feedstock will contribute to this trend. It is imperative to address medium- to long-term food security for food-importing nations and net food-buying households.

In the short term, governments may consider setting up safety nets for the poor and vulnerable through food distribution, targeted food subsidies, school feeding programs and other nutritional support, and import subsidies. In the medium-to-long term, the impact would be mitigated through: (1) reducing the overall future demand for land for biofuels, and (2) increasing overall productivity in the agricultural sector.

Deploying non-food feedstocks, such as jatropha and sweet sorghum, and restricting plantations to land unlikely to be cultivated for food, as well as promoting the rapid commercialization of second-generation biofuels, could reduce demand for new land. However, challenges include a better understanding of the agronomy of non-food feedstocks, identification and delineation of “underutilized land,” and technical and cost issues relating to cellulosic ethanol technology.

Increased productivity within the agricultural sector can be realized through intensification and yield improvements on existing lands. Intensification is not limited to crop yield improvements; improved land management and crop rotation can, for example, reduce the area required for cattle grazing, potentially freeing up acreage for biofuels. Also of significance is to reduce post-harvest and storage-related waste of food grains in developing Asia. In India, for example, 20-40 percent of harvested crops perish because of inadequate post-harvest infrastructure, transportation, and storage. In a widely reported 2007 announcement, India’s Minister for Food Processing Industries, acknowledged that more than US\$10 billion worth of food grains are wasted every year—an amount sufficient to feed all 220 million people in the country living below the poverty line in India for almost a year (RNCOS, 2007).

INDIGENOUS RIGHTS AND LABOR STANDARDS

As discussed in **Section 6**, the implementation of mandates and quantitative targets in many cases can create the incentive for land grabbing, deceit and coercion of indigenous and marginalized communities,

and degradation of the environment. Workers on large plantations—especially migrant and temporary laborers, and women—are vulnerable to abuse, poor or hazardous working and living conditions, low wages, coercion, and lack of representation.

These issues can be addressed through the implementation of a framework of rules, combined with strict enforcement and a consumer-led push for transparent and effective certification systems. Best practices to avoid these repercussions are outlined in the standards and criteria of various monitoring bodies, such as the Roundtable on Sustainable Palm Oil (RSPO) and the Roundtable on Sustainable Biofuels (RSB) (see **Section 7.6**). They include: transparency; consultation with all stakeholders, especially rural and indigenous groups; fair compensation for land use or purchases; and adherence to international labor standards. Because of the diversity in feedstocks, the climates and soils in which they grow, and political and economic conditions, however, each decision to proceed with biofuels development involves different parameters and considerations, and will have to be evaluated on an individual basis.

Governments and international NGOs and agencies must continue to foster multi-stakeholder entities, like the RSB and the RSPO, to encourage application of labor and indigenous rights standards and criteria. Internationally recognized standards are perhaps the only mechanisms that enable distant consumers to make informed decisions about the trade and use of biofuels when local governments fail to adequately monitor the environmental and social implications.

PARTICIPATION OF SMALLHOLDERS

Comparative experiences suggest that the production of biofuels, especially ethanol, is more competitive with large-scale industrial production because of the high investment costs related to processing. Small-scale and large-scale production, however, need not be mutually exclusive. Governments can promote contract farming, in which processors purchase from smallholders under terms agreed to through contracts.

The examples of smallholder participation in the oil palm industry in Malaysia, and to a smaller extent in Indonesia, can point the way to fair and sustainable practices

Box 20. Diagnosing Fertilization Needs in Thailand

Thai oil palm growers are encouraged to use foliar analysis to reduce costs, boost yields, and enhance competitiveness. Foliar analysis helps to discern nutrient status and tailor fertilization needs and timing, boosting yields while reducing fertilizer waste. The German development aid agency GTZ teamed up with palm oil crushing mills in southern Thailand to set up a special laboratory to undertake the analysis. This lab and related technical assistance programs assist smallholders whose production costs (THB 2.7 per kg) are much higher than that of large plantations in the same location (THB 1.5 per kg).

Source: Pongvutitham, 2009

and frameworks that ensure smallholder participation (**Section 6.3.2**). Regardless of the mechanism, promoting smallholder participation almost always requires active government policies and support through appropriate investment in: public goods (infrastructure, research extension, etc.); rural finance; market information; market institutions; and legal systems.

7.4 TECHNOLOGY RESEARCH AND DEVELOPMENT

Countries face many challenges balancing support for struggling biofuels industries today and providing support for higher performance second-generation biofuels tomorrow. First- and second-generation fuels will need to coexist in the near- to medium-term, with first-generation biofuels providing the bulk of supply. Policies should include a flexible R&D framework that can adjust to changing conditions, avoid direct support in the form of subsidies, and allow for decrease of support over time, to aid the transition from first to second-generation technologies.

FIRST-GENERATION BIOFUELS NEEDS

Since no major technological breakthroughs in biodiesel transesterification or ethanol fermentation are expected, policy support and innovation must be aimed at efficiency improvements within the supply chain and agronomic practices that can increase yields. The overall potential for yield increases depends on crop genetic improvement efforts; the ability to rapidly transfer agronomic advances to small farmers (**Box 20**); and adequate access to water, fertilizers, and agro-chemicals. Relative to other developing regions, Asia has been successful in increasing yields for major food crops. The research techniques and

farm extension techniques that have worked in the past need to be geared toward addressing yield enhancement requirements for biofuels crops—especially relatively new candidates such as *jatropha* and sweet sorghum.

SECOND-GENERATION BIOFUELS NEEDS

Even at high oil prices, second-generation biofuels will probably not mature in developing Asia for some time without significant additional government support. Considerably more research, development, demonstration, and deployment investment is needed to ensure future feedstock production and processing is sustainable and advanced conversion technologies are identified and developed.

Despite potential advantages over first-generation technologies, second-generation biofuels (and third-generation fuels such as algae) are not yet commercially mature, and their costs are significantly higher than for current biofuels. These feedstocks have many positive social and environmental attributes. However, improper deployment can lead to many of the issues that constrain grain-based biofuels. Choice of location and appropriate management practices are critical in ensuring sustainability. Much of the research on the agronomy, yield, and environmental impacts of second-generation “energy crops” is conducted in the US and EU (McLaughlin and Kszos, 2005; Tharakan et al, 2005, Tharakan et al, 2006). Similar research is needed in Asia.

The design and implementation of environmental performance standards—including a prohibiting such practices as growing invasive species, removing excessive annual crop residue, providing incentive payments for avoided GHG payments, or retaining natural spaces as

wildlife corridors—would bolster the sustainability of second-generation feedstocks.

Much work remains to improve second-generation conversion pathways, reduce costs, and improve the performance and reliability of conversion processes (IEA, 2008b). Policies must be carefully crafted to avoid unwanted consequences and delayed commercialization.³ For both main biofuels processes—biochemical and thermochemical—policies are needed to support further technological improvements. Biochemical pathway research will likely yield better enzymes and catalysts, but thermochemical pathways present opportunities to manufacture a wider array of fuels. Demonstration projects can test the production chain under industrial conditions to determine which pathway is best suited to local conditions. Policies that foster investment and partnerships would ensure research does not lag. Once proven, the transition from first- to second-generation technologies should be monitored closely and supported through policy incentives for sustainable feedstock production and technical assistance (IEA, 2008b).

CROSS-CUTTING POLICY AND RESEARCH IMPERATIVES

As nations expand their biofuels programs, further research is needed to understand the life-cycle impacts of biofuels pathways on air, soil, water, land use, and ecosystems. Industry, academia, and the government must collaborate closely to evaluate the potential impacts on a country's fueling infrastructure (including impacts on the vehicle stock) and options for materials, storage,

transmission, distribution, and dispensing operations. Investments are needed to strengthen research capabilities, and unifying fuel and sustainability standards can further develop markets. Finally, the technical, economic, and environmental performance of biofuels has to be evaluated against the alternatives—namely the use of biomass for electricity generation or plug-in hybrid electric vehicles (**Box 21**). Preliminary analyses along these lines have been undertaken for OECD countries, but not for Asia.

7.5 SUPPORT FOR COMMERCIALIZATION OF SUSTAINABLE BIOFUELS

Despite unprecedented growth and investment globally, the biofuels industry is in early development. The past five years have seen many investors rush into the sector. While venture capitalists and speculative interests have come in with a short time horizon and expectation of quick returns, the oil majors (public and private) have followed a more cautious approach of integrating biofuels into their supply-mix in a phased manner.

Investments by first-movers have shown mixed success. The four main factors influencing profitability—fuel prices, feedstock price and availability, government regulation, and conversion technologies—are in flux, making investments highly risky. Several actors, especially those seeking quick returns, have exited the market. Currently, investor confidence in this sector is low, and future investments appear to be flanked by risk and uncertainty. Market

Box 21. BP and DI Oils Joint Partnership

BP and DI Oils have entered into a joint partnership to produce jatropha on around 1 million hectares in Southern Africa, India, Southeast Asia, and Central and South America. BP will invest close to US\$90 million out of a total joint venture investment of US\$160 million over the next five years. The project will seek to cultivate jatropha through directly managed plantations on owned or leased land and through contract farming and seed purchase agreements.

Much of the jatropha oil produced from the plantations will be used to meet local biodiesel requirements with any excess exported to Europe.

Source: BP, 2008

³ There are opposing viewpoints on structuring governmental support for second generation biofuels. According to one view, first-generation support impedes second-generation development since direct support (grants and subsidies) does not encourage innovation. On the other hand, second-generation fuels could potentially benefit from first-generation support and enable sustainability lessons to be passed on. In either case, policies should acknowledge that developing second-generation fuels is a long-term goal that requires an integrated transition strategy, taking into account their complementary yet distinct policy requirements.

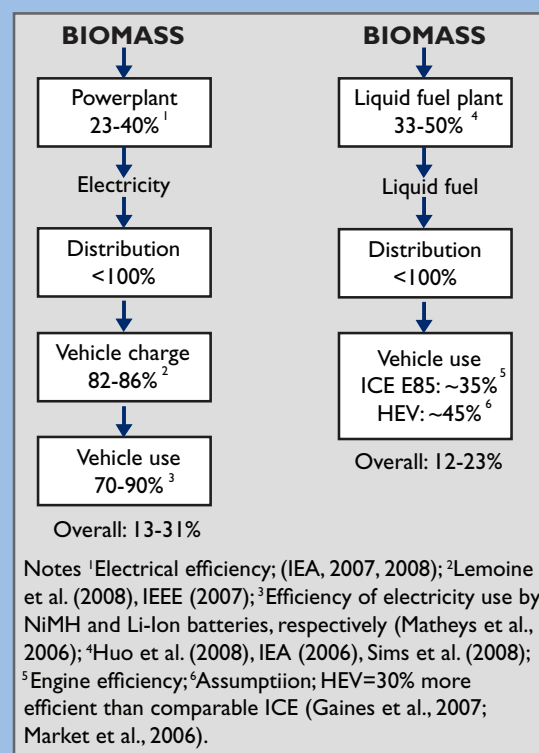
Box 22. Comparing the Efficiency of Biomass-based Electricity and Liquid Biofuels for Transport

Biofuels can be used in the transportation sector in two ways: (1) as liquid fuels used in conventional internal combustion engines (ICE) or in hybrid electric vehicles (HEV) or (2) to generate electricity to be used by plug-in hybrid electric vehicles (PHEV). The relative efficiency of the two pathways is a result of the conversion efficiencies that characterize each of the steps along the biomass-vehicle chain. The inset figure shows the energy conversion efficiencies along the two pathways. In both cases, the system boundaries are set to measure efficiencies in terms of energy delivered to the vehicle fleet.⁴

Under optimal conditions, biomass-based electricity used in a PHEV delivers overall higher system efficiency than using biomass-based liquid fuel in an ICE or HEV. This is due in part to higher energy efficiency of PHEVs (inset table⁵). In the developing Asian context, the lower range of efficiencies applies, making the two system efficiencies in both options comparable. This is because developing Asia often has lower power plant efficiencies, unreliable grids and higher transmission and distribution losses, combined with the higher cost of PHEVs. In Asia, the use of liquid biofuels in HEVs or ICEs may be a more viable option than PHEVs (Gaines et al., 2007). Moving to a flex-fuel HEV would provide additional benefits.

For both options, the lower end of the ranges are representative of common conditions in Asia, the upper end represents optimal conditions.

BIOMASS FOR ELECTRIC VEHICLES VS. BIOMASS FOR LIQUID FUELS



ENERGY USE EFFICIENCY OF DIFFERENT VEHICLE TECHNOLOGIES

Vehicle Type	Energy Use (MJ/mile)			Efficiency Gain over Conventional Vehicle
	Gasoline	Electricity	Total	
Conventional	4.65	NA	4.65	NA
HEV	3.27	NA	3.27	30%
PHEV20	2.09	0.50	2.59	44%
PHEV40	1.59	0.76	2.35	49%

Source: Based on Markel et al. (2006)

⁴ The calculated efficiencies ignore the energy contents of co-products of liquid bioenergy fuels (e.g., fuel gas, heavy oils, and crop meal (Huo et al., 2008) and electricity production (heat). Inclusion of co-product energies would increase their overall efficiencies and may affect their relative performance. This analysis is included here as the focus is on the efficiency of biomass-based energy use in the transport sector.

⁵ PHEV20 is a vehicle with a 20 mile range using the onboard battery; PHEV40 is a vehicle with a 40 mile range using the onboard battery.

entrants will have to undertake a variety of strategies and place investments carefully to mitigate ongoing risks. Returns on investments (both public and private) and the rate of market maturation will depend on how government policy, R&D, and costs evolve.

FIRST-GENERATION COMMERCIALIZATION

Increased supply chain efficiencies and reduced production costs are key to enhancing the competitiveness of current fuels. High costs related to feedstock price and availability, and oil prices create uncertainty and risk. With the exception of Brazil, production costs of current biofuels are high due to high feedstock prices. As costs rise due to increasing demand on already constrained supplies, biofuels producers will need a reliable source of feedstock. Vertical integration backwards to link up with feedstock supply would be prudent (**Box 22**). Vertically integrated players tend to not only achieve greater cost efficiencies by better management of the supply chain, but also are better able to absorb price fluctuations. Using residues to generate electricity in processing plants and selling co-products can diversify revenue and reduce processing costs.

The cost curve for biofuels production is not steep, so companies will need to bet on the technologies, feedstocks, and locations best suited to long-term viability, in close alignment with government incentives. Public-private partnerships can facilitate technology dissemination and best practices.

Brazil's ethanol production has thrived through its technical assistance program to increase yields, efficiencies, and process chains, and by encouraging innovation. Similar measures are needed to increase production efficiencies and lower costs in Asia. Policymakers will need to ensure investments occur in a timely fashion and are directed to the most economically effective biofuels.

SECOND-GENERATION COMMERCIALIZATION NEEDS

Second-generation biofuels are not commercially produced anywhere in the world. Over time, the cost of cellulosic technology could decrease to as low as \$0.25 to \$0.60 per liter—a huge savings compared to current production costs in Asia (IEA, 2008b). Because commercialization of second-generation biofuels will be capital-intensive and more likely to accelerate in developed countries; technology-sharing agreements and joint ventures are important for

disseminating technologies in Asia. With favorable climates for biomass production, Asian partners in joint ventures might contribute host sites for demonstrations and the first commercial plants in exchange for domestic access to intellectual property owned by international companies and avenues for entering local markets (McKinsey, 2007). Public-private relationships can coordinate efforts along the value chain and minimize risk and volatility. No single company possesses all the skills needed in agronomics, process technology, feedstock and fuel procurement, storage, distribution, refinery operations, commodity trading, and shaping local regulation. Industry consortiums are important to help direct the market and work with regulators to identify areas for cooperation and further development.

Governments also have a role to play in encouraging R&D to accelerate second-generation biofuels and biorefineries capable of producing a range of products. Such investments offer more promise than merely adopting trade barriers or supporting domestic production (OECD, 2007). Research is needed to advance flex-fuel vehicles, develop pilot and commercial plants, and coordinate industry initiatives with government policy.

THIRD-GENERATION COMMERCIALIZATION NEEDS

Currently most research on efficient algal-oil production for biodiesel purposes is being done by the private sector in small pilot-projects. Commercial microalgae culture by the food industry is well established but these large commercial systems are almost always an open-air system design because they are less expensive than closed systems (as described in Section 3.3, these systems must directly provide all necessary nutrients, light and CO₂). The drawback to open systems is that there is no control over water temperature and lighting conditions, and they can be vulnerable to contamination. Also, the number of species that has been successfully cultivated for biodiesel in an outdoor system is relatively small. However, closed systems are very expensive and can be difficult to scale up. Closed systems are operated indoors with artificial lighting so they can have high energy costs as well. Further R&D is needed to bring down the cost of closed algae production systems, develop hardy and high-yielding algae strains, and further demonstrations are needed to test a variety of growing and processing technologies.

Box 23. Biofuels and the Carbon Market

Among the many mechanisms in the carbon market, the 1997 Kyoto Protocol's Clean Development Mechanism (CDM), one among several alternatives within the global carbon market, provides an incentive for clean energy projects by establishing a mechanism by which developed countries with GHG emissions reduction targets have the opportunity to make cost-effective investments in emissions reduction projects in developing countries. However, of the 632 biomass energy projects in the CDM pipeline worldwide as of November 2008, only seven were biodiesel, including three in Asia (CD4CDM, 2008), and to date there are no bioethanol projects. Principally, this is due to the fact that the only CDM Executive Board (EB) approved methodology for biofuels is for biodiesel derived from biogenic waste oils or fats (UNFCCC, 2008). No baseline or monitoring methodologies have been approved by the Executive Board for crop-based biofuels, mainly because there are debates about how to calculate and measure GHG reductions from biofuels projects, including emissions from feedstock production. However, the EB has approved dozens of cogeneration projects using bagasse and palm oil empty fruit bunches (EFB) without requiring any accounting of feedstock production emissions; biofuels developers feel they are subject to a double standard. For the CDM to provide a viable opportunity for biofuels projects to receive investments and a revenue stream through carbon credit payments, methodologies will need to be developed that address concerns over additionality, double counting, emissions leakage.

7.6 SCALING UP DECENTRALIZED BIOFUELS

Small-scale biofuels industries' needs differ from commercial-scale ventures. Most projects in decentralized biofuels production are at a pilot or demonstration level. These projects need to be supported and replicated through policy, technical assistance programs, and partnerships. Biofuels production on a small, local scale has the potential to benefit impoverished rural populations by providing options for cheaper transportation fuel, and partial electrification. On the whole, these benefits are more desirable and at a lower environmental and social cost than the potential—and questionable—benefits of commercial biofuels in blending mandates for transportation.

Inherent obstacles to decentralized production include: lack of funding; intermittent interest by policymakers; and technical challenges using crude feedstocks in engines, including lack of support by original equipment manufacturers (OEMs).⁶ To some extent, access to reliable and sound technologies, strong stakeholder coordination, public-private partnerships, and strong government support can address these challenges.

POLICY, FINANCE AND TECHNICAL NEEDS

To replicate decentralized applications across countries there must be strong government support. Ensuring policymakers understand the strong arguments for decentralized biofuels from an economic, social, and environmental perspective is key to making decentralized biofuels a part of national energy policy. The enabling environment in many rural areas is absent, including infrastructure, access to seeds and credit markets, and even information on agronomic developments. Governments and NGOs play a vital role in kick-starting local, rural industries and providing financing and technical assistance. To expand decentralized production of fuels and electricity, financing is needed to enable local communities to acquire generators, oil presses, filters, and even stoves that use gas rather than raw biomass. Rural financing sources and credit markets are often poorly developed and difficult to establish (ESMAP, 2005). Therefore, the participation of local and international NGOs and multilateral and bilateral aid agencies is especially important to help provide the necessary equipment as well as the training required to enable communities to grow and produce their own fuels. Assisting smallholders in building cooperatives, marketing associations, partnerships, and joint ventures will aid in the formation of local biofuels industries as in other agricultural markets (**Box 24**).

6 In many cases, OEMs will void warranties if crude vegetable oils are used in their engines

Decentralized biofuels production systems must be regarded as disconnected from commercial biofuels development because otherwise there is a risk that local populations will be exploited for producing feedstocks for national markets without being given a fair price. If communities do embark on streaming their excess feedstock production into commercial markets, NGOs and international aid organizations, again, can play a large role in helping communities find markets for their product at fair prices.

To address technical needs, R&D programs and greater numbers of demonstrations are needed to test the long-term effects of unprocessed biofuels in engines and generators under different operating conditions. Government-sponsored R&D and technical assistance programs can help disseminate best practices and drive innovation toward more straightforward and inexpensive technologies that can be deployed at small scales to produce liquid fuel and generate electricity.

7.7 STANDARDS AND CERTIFICATION NEEDS: WORKING TOWARDS BIOFUELS SUSTAINABILITY

In the last few years, environmental and social concerns have led observers and policymakers to question the inclusion of biofuels in emission reduction plans. Biofuels blending mandates will probably continue, but their pitfalls have escalated calls for standards and certification systems to ensure biofuels are produced responsibly and sustainably (e.g., Cramer et al., 2006). Several standards exist for sustainable agriculture and forestry. Forest Stewardship Council (FSC) certification can be applied to forest bioenergy and second-generation cellulosic biofuels produced from forest biomass. Feedstock-specific approaches include the Better Sugarcane Initiative, Roundtable on Responsible Soy (RTRS), and Roundtable on Sustainable Palm Oil (**Box 25**).

THE ROUNDTABLE ON SUSTAINABLE BIOFUELS

The RSB is a multi-stakeholder initiative spearheaded by the Swiss École Polytechnique Fédérale de Lausanne Energy Center. It brings together diverse institutions, including NGOs (WWF, FSC), energy conglomerates (Shell, BP,

Box 24. ICRISAT - Rusni Distilleries Partnership in India

ICRISAT has formed an agribusiness incubator partnership with Rusni Distilleries in India to test and deploy sweet sorghum with thousands of small-scale farmers. The distillery plant uses the sweet juice extracted from the stalk of the plant (rather than the grain), purchased from local farmers. The plant also has the capability to produce ethanol from sugarcane, corn, and other grains that farmers have in excess in a given year. Under this arrangement, farmers benefit from technical inputs and advice and an assured price for their crop.

Source: ICRISAT, 2007

Petrobras), international agencies (UNCTAD, UNEP), and several European government bodies. In August 2008, the RSB issued “Version Zero” of its global principles and criteria for sustainable biofuels production. These principles aim to be simple, generic (i.e., applicable to any crop in any country), adaptable (i.e., easy to incorporate new technologies), and efficient.

According to RSB’s principles (RSB, 2008), biofuels production must (paraphrased):⁷

- 1) Respect all applicable national laws and relevant international treaties;
- 2) Operate under transparent, consultative, participatory processes in order to diffuse conflict, including the promotion of environmental and social impact assessments and prior informed consent for new projects;
- 3) Contribute to climate change mitigation by significantly reducing GHG emissions when compared to fossil fuels, as determined by a consistent approach to GHG lifecycle assessment and taking into consideration emissions from both direct and indirect land use changes;
- 4) Avoid violations of human or labor rights and ensure decent, safe working conditions, and in particular, avoid slave labor, forced labor, and child labor;

7 “Version 0” of RSB’s principles and criteria can be found at: <http://cgse.epfl.ch/page70341.html>

- 5) Contribute to the social and economic development of local, rural, and indigenous communities;
- 6) Endeavor not to impair food security by giving preference to waste inputs, and degraded or marginalized land use;
- 7) Avoid negative impacts to biodiversity and ecosystems, especially areas of high conservation value;
- 8) Promote practices to improve soil health and reduce degradation, by measuring and maintaining soil organic matter content;
- 9) Optimize the use of water resources through appropriate water management plans, and by respecting existing water rights, both formal and customary;
- 10) Minimize air pollution from production and processing of feedstocks;
- 11) Be cost-efficient, using appropriate technologies to improve production efficiency; and
- 12) Avoid violating land rights and compensate local communities fairly and equitably for agreed land acquisitions.

Notwithstanding the broad nature of these principles, response to the RSB has been positive. The International Social and Environmental Accreditation and Labeling Alliance, a nonprofit organization which assesses the credibility of voluntary standards, accepted the RSB as an associate member. At present, the RSB standard lacks regulatory teeth, given that it only comprises general principles and criteria, with no supporting indicators and metrics. The RSB is undertaking consultations and field tests to develop more specific indicators against which to measure biofuels performance. The results will be in a finalized “Version One” of the standard in 2009. General consensus suggests the RSB will evolve into a third-party certification and verification scheme, enabling producers to claim their biofuels are sustainable.

LIMITATIONS OF CERTIFICATION AND LABELS

For certification schemes, time is a significant challenge, especially with regards to their potential to halt development of forests and peatlands. In the face of unrelenting market pressures, destruction of rainforest and other biodiverse areas will continue. The need for certification is increasingly clear but RSPO and RSB are still in the early stages of development. Gaining consensus on certification criteria, developing methodologies and assessment protocols, and increasing participation takes years. It will be crucial to mobilize and boost membership quickly in order to create a strong market for sustainably produced biofuels, especially in light of Indonesia’s recent removal of a ban on oil palm production on peatlands.⁸

There is much that these biofuels certification schemes could learn from the decade and half of experience with the development of credible forest management performance certification and chain of custody systems for timber products (e.g., FSC). If, over time, biofuels production is used mainly to fulfill domestic mandates, rather than exported to more environmentally discriminating markets (e.g., the EU and US), it is unlikely that instruments like the RSOP and RSB will provide adequate market drivers for sustainability, unless in the coming years RSPO and RSB practices become the operating norm for the industry. It will be important to ensure that mandatory regulatory regimes set up a standard of management practice in Asian countries that applies to all producers while producers selling into certain market segments would take steps to voluntarily comply with RSPO and RSB practices.

There are other barriers that could limit the efficacy of certification and labeling systems for biofuels (Keam and McCormick, 2008). The high costs of verification and compliance favor bigger, more established producers over smallholders. Financial and technical assistance to smallholders, now offered by the Malaysian Palm Oil Association, could help address this issue. A phased certification approach that starts with legal issues and then moves to management—as developed by FSC—would also help smallholders.

8 A recent UNCTAD report concludes that for certification programs to be successful they must be based on internationally agreed principles and criteria (including those from existing forums) that accommodate the differences in environmental, technological and socio-economic conditions of producing countries. It is also important that these programs are quantifiable, verifiable and scientifically informed, and are the result of an inclusive process where stakeholders from various regions are represented. http://www.unctad.org/en/docs/ditcted20081_en.pdf

Box 25. The Roundtable on Sustainable Palm Oil

The Roundtable on Sustainable Palm Oil was established in 2004 to advance the production, procurement, and use of sustainable oil palm products through the development, implementation, and verification of credible global standards, and the engagement of all stakeholders along the supply chain. As an international, multi-stakeholder forum, RSPO members include environmental and social NGOs as well as businesses active in growing, processing, using, and retailing palm oil.

The RSPO's eight fundamental principles are:

- 1) Commitment to transparency;
- 2) Compliance with applicable laws and regulations, especially with respect to land tenure;
- 3) Commitment to long-term economic and financial viability;
- 4) Use of appropriate best practices by growers and millers, especially with respect to the use of water resources, soil fertility, and the use of pesticides and fertilizers;
- 5) Environmental responsibility and conservation of natural resources and biodiversity;
- 6) Responsible consideration of employees and of individuals and communities affected by growers and mills;
- 7) Responsible development of new plantings, including mandating environmental impact assessments and forbidding encroachment on natural primary forest, as well as safeguarding the land rights of local and indigenous communities; and
- 8) Commitment to continuous improvement in key areas of activity.

These principles are broken down into separate criteria, each with its own indicators and guidance. A full description of RSPO's principles, criteria and indicators can be found at www.rspo.org. In late 2007, RSPO launched a certification system to enable audited growers and processors to market palm oil produced according to the criteria. Applicants must meet all criteria and a third-party assessor conducts a strict audit. In 2008, United Plantations became the first plantation to obtain RSPO certification for some operations in Malaysia. They shipped the first RSPO-certified palm oil to Europe in November 2008.

RSPO and its certification program are not free of controversy. Because it has many large oil-plantation members, environmental groups accuse it of "green-washing" environmentally damaging practices and providing inadequate oversight of its certification criteria. Greenpeace condemned the first shipment of RSPO-certified palm oil because United Plantations, while RSPO-certified in Malaysia, allegedly continues to cut virgin forest in Indonesia. Another NGO, Wetlands International, challenged the validity of the certification process by claiming that the first certified palm oil originated from a plantation grown on former carbon-rich peatlands. It charged that the RSPO fails to account for greenhouse gas emissions in its certification process.

An added challenge is the cost of certification. Producers need a high-enough price premium to make the cost and trouble of passing 39 separate criteria worthwhile. Ultimately, sustainability standards are demand-driven. For RSPO and similar mechanisms to succeed, consumers, wholesalers and retailers need to demand sustainable products.

It is uncertain whether restricting trade to certified biofuels violates WTO rules and free trade agreements. Finally, the potential for consumer labels may be limited. Unlike certified coffee or timber for furniture, where the product is directly and completely consumed by the end-user, biofuels when blended with petroleum fuels often constitute only 1-10 percent of total fuel. In this context, it is difficult to communicate the benefits of certified products through labels and create an “emotional bond” that will compel consumers to pay a premium for certified biofuels. If producers receive very little price premium for certified CPO over non-certified CPO, they are unlikely to undertake the extra effort and incurred cost of certification. Undoubtedly, there are other threats to sensitive lands aside from biofuels but robust certification systems are needed in the near-term to prevent biodiversity loss and large releases of GHG emissions from expanded biofuels operations.

THE NEED FOR TECHNICAL STANDARDS

Development of global sustainability criteria for biofuels would likely be easier if consensus is reached on technical standards for biofuels. This is proving to be a slow and difficult process.

Quality standards are most important for biodiesel. Unlike bioethanol, biodiesel varies in chemical composition and performance characteristics depending on the feedstock. In the process of turning natural fats into biodiesel, unwanted reactions and chemical substances can develop, resulting in contamination (IEA, 2008a). Small producers can manufacture and distribute biodiesel, complicating formation of standards that addresses complex fuel and engine requirements, as well as batch testing for quality.

Anticipating that international trade would play an increasing role, the International Biofuels Forum (a governmental initiative among Brazil, China, the EU, India, South Africa, and the US) sponsored a comparative study (TTF, 2007) of existing standards set by the United States, Brazil, and the EU. The study found that ethanol standards (ANP no. 36/2005 in Brazil, EN 15376 in the EU, and ASTM D4806 in the US) outlined parameters in relative harmony, with the significant exception of water content. This suggests that there is very strong potential for reaching an international standard in the future. For biodiesel, on the other hand, the specifications (ANP no. 42/04 in Brazil, EN 14214 in the EU, and ASTM D6751 in the US) are significantly different. The EU's EN 14214 standard for biodiesel, for example, involves 30 different criteria and conditions.

Early steps have been taken in Asia to develop a common biodiesel standard to facilitate trade. An APEC-commissioned study (Hart Energy Consulting, 2007) acknowledged the difficulty of developing a feedstock-neutral biodiesel standard and set forth several approaches. Because biodiesel trade remains limited, progress is likely to be slow.

A lack of standards makes an expansion of biofuels in Asia more likely in the short term. However, in the long-term, this lack of product standards and certification systems will hinder growth prospects by restricting trade and competition. International collaboration will create greater confidence in biofuels quality, sustainable production methods, and the ability to quantify and ensure GHG reductions.

SECTION 8

RATING OF BIOFUELS AGAINST SUSTAINABILITY CRITERIA

The conditions under which different biofuels feedstocks are produced and processed into biofuels determine how sustainable they are as a fuel source. Therefore, it is useful to rate biofuels feedstocks against a holistic set of sustainability criteria to demonstrate whether their impacts on a variety of factors are positive or negative and to determine which feedstocks are the most sustainable for biofuels production in Asia. Below, the predominantly cultivated biofuels feedstocks have been scored against criteria relating to environmental, social, economic, and agronomic issues (**Table 22**). Since sustainability depends on local conditions, as emphasized throughout this report, assumptions and conditions are listed as notes in Table 22 and discussed below.

ENVIRONMENTAL PERFORMANCE

Criteria relating to environmental performance include: water and fertilizer demand; impact on soil quality, biodiversity and land use; emissions of local air pollutants (tail pipe emissions) and net greenhouse gas and energy balances. In general, annual grain crops and sugarcane have high water and fertilizer demands. Sugar beet, sweet sorghum, cassava, rapeseed, jatropha, oil palm and cellulosic feedstocks, on the other hand have low-to-moderate water and fertilizer demands. However, even for these feedstocks, irrigation will result in higher yields. Perennial crops, namely jatropha, oil palm and cellulosic feedstocks, have the least impact on soil quality. All the crops except for jatropha, and cellulosic feedstocks, under current cultivation practices, involve land use change and loss of natural vegetation. Jatropha and cellulosic feedstocks are being targeted for marginalized lands and unutilized lands, and if they are restricted on such lands, it is likely that this will lead to an increase in vegetation cover. Similarly, all crops except for jatropha and cellulosic feedstocks, under current practices, lead to biodiversity loss both from loss of habitat and from the use of monocultures over large areas.

When it comes to local air pollutants, all feedstocks lead to significantly lower emissions of CO, SO_x and particulates.

Rapeseed with high emissions of particulates is the only exception. All biofuels emit a higher amount of NO_x, relative to petroleum fuels. GHG and net energy balances depend on crop characteristics, processing, and growing methods. Under ideal conditions, sugarcane, cellulosic feedstocks and sweet sorghum have the best net energy balance and corn has the worst. Among biodiesel feedstocks, oil palm has the best net energy balance. Assuming no land use change, sugarcane in Brazil, sweet sorghum and cellulosic feedstocks have the best net GHG balance. Among biodiesel feedstocks, oil palm has the best net GHG balance.

SOCIAL PERFORMANCE

Social criteria focus on employment generation potential, impacts on food security, and ability to support small-scale production. Employment generation potential is low to moderate for most crops depending on the degree of mechanization. Jatropha may provide the highest employment potential among all biofuels feedstocks. In terms of food security impacts, all grains and food crops fare poorly. Non-food crops, namely, jatropha, sweet sorghum and cellulosic feedstocks have minimal direct impact on food supply, unless they displace food crops from agricultural land. Ethanol production and therefore ethanol feedstocks have a strong tendency for economics of scale and are most efficient at large scales. Among biodiesel feedstocks, jatropha is ideally suited for small-scale operations.

ECONOMIC PERFORMANCE

Other than Brazilian sugarcane, no other biofuels feedstock is financially viable without subsidies. Cassava from Thailand and corn from China are among the cheapest ethanol feedstocks in Asia. In terms of biodiesel, oil palm is the cheapest. Overall, corn from the US, and wheat in Europe for ethanol, and soybean and rapeseed for biodiesel in the US and Europe, respectively, are the most expensive feedstocks. Cellulosic feedstocks are expected to become cheaper once commercialized.

Table 22. Biofuels Feedstock Performance against Environmental, Social, Economic, and Agronomic Criteria

CROP TYPE		Environmental Impacts								Social Impacts			Economics	Agronomy				OVERALL
		Water Demand	Fertilizer Demand	Soil Quality Impacts ¹	Tailpipe emissions ²	Land-Use Impacts ³	Biodiversity Impacts ⁴	GHG Balance ⁵	Net Energy	Multiple Environmental Benefits	Employment Generation	Impact on Food Security	Suitability for Small Scale ⁶	Production Cost ⁷	Understanding of Production System	Potential for Yield Improvements in Asia	Fuel Yield	
Ethanol	Wheat	P	P	P	M	P	P	M	M	P	P	P	P	P	G	M	P	P
	Corn	P	P	P	M	P	P	M	P	P	P	P	P	P	G	M	M	P
	Sugar beet	M	P	P	M	P	P	M	P	P	P	P	P	P	G	M	G	M
	Rice	P	P	P	M	P	P	M	M	P	M	P	P	P	G	M	M	P
	Sugarcane	P	P	P	M	P	P	G	G	U	M	P	U	G	G	G	G	G
	Sweet Sorghum	G	P	P	M	U	M	G	P	U	M	G	U	U	P	G	P	M
	Cassava	G	P	P	M	U	M	G	M	U	M	G	U	G	G	G	M	M
Biodiesel	Soybeans	P	P	P	M	P	P	M	M	P	P	P	M	P	G	M	P	P
	Rapeseed	M	P	P	P	P	P	M	M	P	P	P	M	P	G	M	P	P
	Oil palm	P	G	G	M	U	U	G	G	U	M	P	G	G	G	M	G	G
	Waste Veg. Oil	na	na	na	M	G	G	G	G	G	P	G	G	G	G	P	M	G
	Jatropha	G	G	G	M	U	M	G	G	G	G	G	G	U	P	G	G	G
2nd generation Cellulosic ethanol feedstocks		G	G	G	M	G	U	G	G	G	U	G	U	P	P	G	G	G

Table Key: **G** = Good, **M** = Moderate, **P** = Poor, **U** = Uncertain, **na** = not applicable

Notes: Assumes that non-edible crops (cassava, sweet sorghum and jatropha) are planted on degraded, marginalized lands, but may still require water and fertilizer

1. Frequent soil disturbance and high fertilizer demand can result in poor soil quality.
2. On balance, biofuels result in air quality improvement, save increased ozone and nitrogen emissions.
3. Domesticated crops require land conversion; sweet sorghum, cassava, and jatropha on degraded land can rehabilitate the land, depending on growing methods.
4. Biodiversity impacts are good if degraded land is replanted and new habitats created; Impacts are poor if crop establishment involves destruction of habitats.
5. These rankings are relative between the crops and assume crops are grown on agricultural or degraded land; all biofuels will be rated as poor if soil carbon is released, especially oil palm on peatland.
6. Biodiesel is well suited to small-scale production because of minimal processing requirements, although small-scale demonstrations of Brazilian sugarcane have taken place.
7. Historically, sugarcane, cassava, and oil palm have demonstrated lower production costs than fossil fuels, but this depends on the price of oil and feedstock

Owing to a lack of a large number of commercial operations, the prices of sweet sorghum and jatropha are unknown.

AGRICULTURAL PERFORMANCE

Agronomic criteria include the level of understanding of crop production systems, potential for improved feedstock yields, and current fuel yield from various feedstocks. While much is known about the agronomy of grain crops, cassava, and traditional oil seeds/crops, very little is known about sweet sorghum, jatropha, and cellulosic feedstocks, suggesting that large gains are possible with these crops. Fuel yield is low in grain crops and relatively high in sugarcane, sweet sorghum, and oil palm. Fuel yield for jatropha varies widely in the literature. It is expected to be high for cellulosic feedstocks once their conversion technologies are commercialized.

CONCLUSION

On the whole, feedstocks most suitable for cultivation in sub-tropical regions of Asia include sugarcane, sweet sorghum, cassava, oil palm, and jatropha. These crops perform well across the most criteria, under the following conditions:

- **Sugarcane:** non-irrigated; low-to-no synthetic fertilizer application; full utilization of co-products including co-firing of bagasse in ethanol distillery; ethanol-driven transport of feedstocks and final product; use of vinasse as fertilizer; plantation does not displace savannah or forest or other food crops.
- **Sweet sorghum:** non-irrigated; low-to-no synthetic fertilizer application; use of co-products, such as co-firing stalks for distillery energy; vinasse as fertilizer; and stalk silage for animal feed; plantation on underutilized lands; intercropped with other crops to improve economics and soil quality.
- **Cassava:** non-irrigated; low-to-no synthetic fertilizer application; intercropped; use of co-products, grown on underutilized lands.
- **Oil palm:** non-irrigated; not planted on peatland, forest or savannah; ideally planted in a polyculture to improve soil quality; co-firing of empty fruit bunches in processing plant and full utilization of other co-products (e.g., glycerin, POME for biogas, bio-fertilizer); provision of biological corridors within plantation to protect biodiversity.
- **Jatropha:** non-irrigated; low fertilizer application; plantation on underutilized lands; intercropped with other crops to improve economic viability; use of co-products (e.g., glycerin and bio-fertilizer).

It must be noted that much of jatropha's performance is based on pilot trials and theoretical assumptions; it is crucial that jatropha be further objectively assessed based on data from pre-commercial and commercial-scale trials. Cellulosic feedstocks appear promising but significant research is needed to develop feedstocks in Asia. Persistent uncertainties and the current high costs and lack of commercialized production and conversion technologies limit their deployment in Asia.

SECTION 9

KEY CHALLENGES FOR DECISION-MAKERS

Biofuels development in Asia is a complex interplay of issues and trade-offs, with a diversity of stakeholders and viewpoints. A vital element of any assessment of biofuels production in developing Asia is to understand the perspectives and priorities of various stakeholders. Capturing the points of view of multiple stakeholders helps identify areas of concern, as well as knowledge and implementation gaps.

The authors consulted with sector representatives (government, industry, NGOs, trade associations, and other stakeholders) in each country to gain first-order knowledge on the status of biofuels development. The information that was gathered is summarized in two parts. The first part highlights recurring issues, questions, and key observations raised by the stakeholders about the status of biofuels development in their own countries. In the second part, this information has been combined with a desk review and analysis of pertinent information (presented in the preceding sections), to provide a summary presentation of the key issues facing biofuels development in each country, organized into five categories.

9.1 KEY ISSUES AND OBSERVATIONS BY COUNTRY STAKEHOLDERS

CHINA

According to Chinese stakeholders, the scope of biofuels development in China is significant, for both biodiesel and ethanol. China's policies are further developed than those of a number of other Asian countries. There are incentives for biofuels (although currently only available for larger companies), as well as significant R&D efforts at private and public facilities. Although there is a cellulosic ethanol pilot plant in China, stakeholders feel that there needs to be a higher level of R&D on cellulosic ethanol technology and microalgae-based biodiesel. Some stakeholders believe that government actions have been too conservative, while others feel more clarity is needed to further delineate food or non-food feedstock for

ethanol production. Some commented on the inoperability of existing policies.

Stakeholders also commented that because of the limits of China's land resources, scarcity of feedstock has already become a common obstacle to the development of biofuels. There is talk of promoting jatropha, but not much acreage is reported to be available. Cassava chips imported from Thailand have been a feedstock for ethanol in the recent past. Because more than 50 percent of China's biodiesel comes from food oil (restaurant waste oil, food waste oil, and return oil), many believe that the development of biodiesel may have more positive than negative impacts on China's food security. Some estimates suggest that there is an even greater potential for biodiesel from waste oil. However, China's current level of biodiesel production is not supported by subsidies and is wholly dependent on market price, making profits highly volatile. Finally, some stakeholders thought that biofuels in China may not bring net GHG reductions when considering the full production lifecycle, and that additional research is needed.

INDIA

Stakeholders indicated that current efforts in India are targeted toward biodiesel and are at a very early stage. Stakeholders commented on the need for government action, including attention to policy and financing frameworks, R&D, and CDM opportunities. At least one private sector stakeholder believes that to be sustainable, government policy should be directly tied to poverty alleviation efforts. Another private stakeholder indicated that the government should adopt the same approach that it adopted for biomass power generation (e.g., promote zoning and provide subsidies). Lack of availability of large tracts of contiguous lands is a major problem. Also, recent problems surrounding land acquisition by the private sector for manufacturing and export processing zones has resulted in increased opposition and scrutiny of land acquisition for any project.

Stakeholders also believed that there has been insufficient research on cellulosic ethanol and micro algae-based biodiesel. They highlighted the need for dedicated feedstock research; the need to identify superior clone/genotypes of important species that can produce a better quality and quantity of oil; and the need for a biodiesel supply chain. Specific to jatropha and other potential biodiesel feedstocks, they cited seed collection as a major constraint: collection points are far from inhabited and accessible areas, with no storage facilities near the collection points, no passable roads to facilitate the transportation of seeds, and other barriers. The general view is that failing any major breakthroughs, jatropha and similar feedstocks will be confined to small-scale production in India. Stakeholders were not confident that India can meet its biofuels mandates, if implemented.

INDONESIA

Responses from Indonesian stakeholders suggest that feedstock availability does not seem to be an issue. Indonesia's main biodiesel feedstock is CPO, with a well-established industry and potential for increased production. The government has expressed a strong interest in biofuels development but has moved cautiously to implement policy. As a result, stakeholders complained about poor coordination among government agencies. More specifically, they said that there is no coherent policy to guide plantation and processing development, and to facilitate supply chain improvements. Pertamina, a state-owned company, voluntarily adopted a target of 5 percent biodiesel in 2007, but then within months, and in response to rapid increase in the price of CPO and lack of clear financial support from the government, had to reduce it to 2.5 percent and then 1 percent.

Stakeholders believe that past CPO government mandates have helped develop the market. However, it has been difficult for small producers, as Pertamina essentially has a monopoly on the market. The situation in Indonesia is also affected by geography. Local authorities were given much greater autonomy to award concessions for crops and timber with little central oversight. This has made transparency and enforcement of regulations, including environmental regulations, almost non-existent. Even though the government has said that no new forest will be converted, deforestation, along with infringements on labor and indigenous rights, has continued. Stakeholders also

commented that contracts are difficult to enforce, and that provincial governments have more power than the central government to implement biofuels projects.

International NGOs, and at least one local NGO, were of the opinion that oil palm has resulted in severe land clearing and that more could occur, especially on the island of Borneo. Palm oil is often a front for forest clearing and timber extraction—and oil palm planting requirements are not met—leading to degradation of forests. Some NGO stakeholders believe jatropha should be used for energy self-sufficiency in villages to promote job creation and reduce poverty, rather than as a large-scale feedstock, since jatropha is unproven commercially. In addition, the government should focus on development of high-quality seeds before starting pilot plantations. Stakeholders believe that the EU discriminates against Malaysian and Indonesian palm biodiesel. The European-based Roundtable on Sustainable Biofuels has different standards than the Roundtable on Sustainable Palm Oil, making it difficult to meet certification requirements for both.

MALAYSIA

The dramatic fall in petroleum prices in November–December 2008 raises the question of commercial viability of palm oil biodiesel in the near term. However, stakeholders remained positive about the long term, since palm biodiesel is a lot less expensive than European rapeseed biodiesel. Stakeholders commented that small companies are looking at jatropha and microalgae as feedstocks for biodiesel, but face difficulties in rationalizing and scaling up production as a practical large-scale option. Some stakeholders maintain that the expansion of Malaysia's oil palm area has occurred primarily through conversion of other tree crop plantations, such as rubber, cocoa, and coconut, contrary to NGO claims that rainforests have been cut down for oil palm plantations. Other stakeholders feel that in reality, while other crops may lead to more deforestation than oil palm, future development plans will likely lead to rainforest conversion. For instance, under the Sarawak Corridor of Renewable Energy (SCORE) initiative, plans include increasing the state's palm oil acreage from 400,000 hectares to 1 million hectares. The additional 600,000 hectares are likely to come from a combination of undeveloped land, which may include idle land, and rainforest.

Some believe that the public sector has no role in biofuels except for R&D on second-generation biofuels since there is little coordination in the government on biofuels as a part of energy policy. Stakeholders support the government's plan to reinstate a national B5 mandate, since the export market to Europe has dried up. This is especially true since producers are familiar with sustainability certification, but believe there is only a slight price premium associated with the certification required to reach EU markets.

PHILIPPINES

Significant developments are taking place in the biofuels sector in the Philippines. The Biofuels Law created the National Biofuels Board to ensure only marginal and idle lands are utilized for biofuels production, rather than agricultural land. The focus for the domestic biodiesels industry is to lower the cost of coco-methyl-ester biodiesel—currently more expensive than petroleum-based diesel—by improving coconut productivity through fertilization and small-scale biodiesel processing facilities at the village level. CME took off due to strong private-sector interest in production, a ready supply of feedstock, and minimal improvements needed in manufacturing infrastructure.

Ethanol production has not grown as much as CME due to very high initial investment costs, tedious loan processing, and concerns about ensuring a sustained supply of feedstock. Similarly, companies interested in investing in and producing jatropha are concerned about whether there is a stable market. There is also a general lack of capital and financing, problems consolidating contiguous areas for jatropha plantation, and limited knowledge on the technical and economic potential of jatropha development and management. Available tracts of underutilized lands may not be attractive to potential commercial investors but a number of NGOs closely monitor the use of agricultural land to ensure that none is diverted to biofuels plantations. Some producers are entering into contract farming or off-take agreements with companies that do the processing, such as the Philippines National Oil Company-Alternative Fuels Corporation (PNOC-AFC).

SINGAPORE

Consultations were held in Singapore because it is a major biofuels processing and trade center. Stakeholders remarked that if a blend is less than 3 percent biodiesel, biodiesel fuel

standards are not needed. Stakeholders indicated ethanol is competitive even with oil at US\$40 per barrel; however, some private companies do not prefer corn as a biofuels feedstock due to food price considerations.

Stakeholders indicated that current options for feedstock are limited. There is potential for expanding sugar-based ethanol in Indonesia, but land rights, political issues, and opposition by some NGOs can make it difficult to develop this potential. Jatropha has far to go before it can become a large-scale source of biodiesel. Some stakeholders thought that oil palm is the wrong feedstock for biodiesel, as the demand for food products from oil palm is high. Overall, prospects for biodiesel are not good in the near term, but operations that use waste oil and animal fat would do well, because of lower costs. A fallout from the recent increase in food prices has been that used cooking oil is exported as virgin oil (through informal channels) and re-sold in neighboring ASEAN countries, making it harder to source this oil in Singapore as a feedstock for biodiesel operations.

THAILAND

Thailand, according to stakeholders interviewed, has a strategy for biofuels, but details (such as mandates) constantly change and some measures are not consistent. Stakeholders stated that there is not enough support for agriculture and that unsatisfactory coordination between ministries is a challenge. The primary barrier to ethanol production is government pricing policy. The government purchases ethanol based on the Brazilian export price, plus transportation costs, and other expenses, including insurance. However, Thai ethanol producers get squeezed by this pricing policy because current production costs are higher than the Brazilian price parity. If pricing issues are resolved, there is sufficient feedstock and capacity to meet immediate needs. However, there is also a general lack of consumer confidence in ethanol and since there is still a choice between ethanol blends and gasoline, demand for ethanol is low.

The situation is different for biodiesel. There are limited opportunities to expand feedstock production for biodiesel because there is not sufficient excess palm oil production to supply biodiesel producers and marginal land that is available for expansion would produce lower yields. Thailand has also banned the import of CPO, further constraining supplies.

Some plantations have reported financing problems. It is difficult to get credit because investing in biofuels is considered high-risk. Government bureaucracy also dissuades producers. To improve the overall productivity of cassava for ethanol and palm oil for biodiesel in Thailand, training on best-practice cultivation methods are needed to improve yields, especially for smallholders.

VIETNAM

Stakeholders said that Vietnam's small but growing biofuels industry's biggest priorities are start-up costs, improving yields, and establishing a supply chain. The feedstocks being used are a reflection of available resources and capabilities. Generally, biodiesel is made from catfish fat, and ethanol is distilled in small amounts from agricultural crops. Fuels produced from other feedstocks may not meet current fuel standards. Stakeholders confirmed that jatropha is still in the R&D stage, with plantations targeted mainly for idle, unused, and mountainous lands or cultivation on low-productivity land.

Stakeholders also noted issues with transporting and delivering ethanol, which adds to costs. Generally, ethanol is neither transported efficiently nor stored properly, and the price of the ethanol used to mix with gasoline is high. Thus, bioethanol is more expensive than gasoline at current prices. Overall, stakeholders highlighted issues related to feedstocks shortages and the need for greater government support to develop the country's biofuels industry.

9.2 KEY ISSUES BY COUNTRY

Biofuels development needs are complex and vary depending on fuels, feedstocks, available resources, and policy and technical developments, as well as socio-economic impacts. It is therefore useful to evaluate the primary concerns or issues for a given country and to identify cross-cutting themes that could benefit from regional cooperation. Country-level issues have been classified into five broad categories in **Table 23**: policy development, technology development, available resources, infrastructure development, and social impacts, and broken down further into sub-categories.

SUB-CATEGORY DESCRIPTIONS:

Biofuels Incentives: Indicates whether policies are in place to provide financial incentives (e.g., price support or consumption/production targets).

R&D Support: Indicates whether policies and program funds are in place to support the research and development of biofuels.

Fuel Standards: Indicates whether standards for biofuels exist. A lack of standards can have marketability implications for locally produced fuels.

Ethanol Production Technology: Indicates the availability of technology locally for the production of ethanol.

Biodiesel Production Technology: Indicates the availability of technology locally for the production of biodiesel.

Agronomy and Crop Science: Indicates ongoing research on feedstock and suitability of crops for biofuels production.

Land Availability: Indicates availability of land for large-scale biofuels crops.

Water Availability: Indicates availability of water for large-scale biofuels crops.

Feedstock: Indicates availability of feedstocks for biofuels conversion (diverted from other uses).

Delivery and Handling: Indicates whether a strong infrastructure system exists to deliver and handle feedstock and fuels.

Production Scale: Indicates current production capacity (S: experimental or small-scale, L: large-scale).

Support to Small Landholders: Indicates whether policies are in place to support conversion to biofuels crops by small landholders.

Table 23. Summary of Biofuels Issues by Country

ISSUES		China	India	Indonesia	Philippines	Thailand	Vietnam	Malaysia	Singapore
POLICY MECHANISMS	Biofuel Incentives	Yes	Yes	Yes	Yes	Yes	Yes(1)	Yes	Yes
	R&D Support	Yes	Yes(2)	Yes	Yes	Yes	No	Yes	Yes
	Standards for Fuel	Yes	No	Yes	Yes	No	Yes	Yes	Yes
TECHNOLOGY DEVELOPMENTS	Ethanol Conversion Technology (3)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Biodiesel Conversion Technology (3)	Yes	Yes	Yes	Yes	Yes	Yes(4)	Yes	Yes
	Agronomy & Crop Science: BHP	Yes	No	No	Yes	No	No	Yes	NA
AVAILABLE RESOURCES	Land Availability	No	Yes	Yes	Yes	No	Yes	Yes	No
	Water Availability	No(5)	No(5)	Yes	Yes	Yes	Yes	Yes	No
	Feedstock Availability	Yes	Yes	Yes	Yes	Yes(6)	Yes	Yes	No
INFRASTRUCTURE DEVELOPMENTS	Fuel Delivery & Handling	Yes(7)	No	No	Yes(8)	Yes	No(9)	Yes	Yes
	Scale of Production	L	S	L	L	L	S	L	L
	Demonstration Projects	Yes	No	Yes	Yes	Yes	No	Yes	Yes
SOCIAL IMPACTS	Support to Small Landholders	NI	Yes	Yes	Yes	Yes	NI	NI	NA
	Support to Landless and Indigenous People	NI	Yes	Yes	Yes	NI	NI	NI	NA
	Competition with Food Supplies	Yes	No	No	No	Yes(10)	No	No	NA

Table Key: **NA** = Not applicable, **NI** = No information, **L** = Large scale, **S** = Small scale

(1) Vietnam currently has limited support for Ethanol only.

(2) India has conducted extensive research on Biodiesel, but not Ethanol

(3) There is currently a wide range of fuel conversion technology under development, depending on feedstock type

(4) Vietnam has a number of small-scale biodiesel plants using catfish fat as feedstock

(5) Water supplies for jatropha not available for certain areas

(6) Thailand currently has little biodiesel feedstock under development

(7) China has the most extensive handling network, but the development vary by region

(8) Vietnam noted delivery and handling issues with ethanol due to its hydrophilic tendencies.

Support to the Landless and Indigenous

Communities: Indicates whether policies are in place for job creation, informed consent, social safety nets, etc.

Competition with Food: Indicates whether biofuels present a major threat to food production.

CONCLUSION

Looking at biofuels development from a regional perspective helps distill challenges facing the industry. Some issues reflect a particular focus in a country, but generally all countries need to develop consistent fuel standards and increase crop R&D. Water is a major issue, particularly for India and China. Finding suitable land will be an ongoing battle between competing interests, although most countries claim to have land available for expansion. Feedstock availability varies by crop. While most countries have adequate feedstocks for current production (though not necessarily mandates), local shortages are apparent and will likely become a greater issue in the future. Fuel handling and delivery are of particular concern for India, Indonesia, and Vietnam, since infrastructure may be weak and does not always reach remote locations. All but India and Vietnam have large-scale production facilities, but more could be done to improve smallholder participation in all countries. The degree to which biofuels compete with food varies, but China and Thailand are most concerned because agricultural land is largely developed. These areas signify where biofuels development must proceed with caution and where additional support and development is needed.

9.3 DECISION-MAKING APPROACHES AND METHODS

This report has highlighted the difficulties and contradictions presented by the production of biofuels from agricultural crops in Asia. The environmental, social, and economic viability of currently available (mostly first-generation) biofuels feedstocks remains uncertain, especially as a result of the great variation in the characteristics of the feedstocks themselves, including the soils, climates, regions, and social contexts in which they are grown. This atmosphere of uncertainty makes it difficult for decision-makers to assess the usefulness of biofuels and to make appropriate choices on how to structure biofuels policies. Policy-makers as well

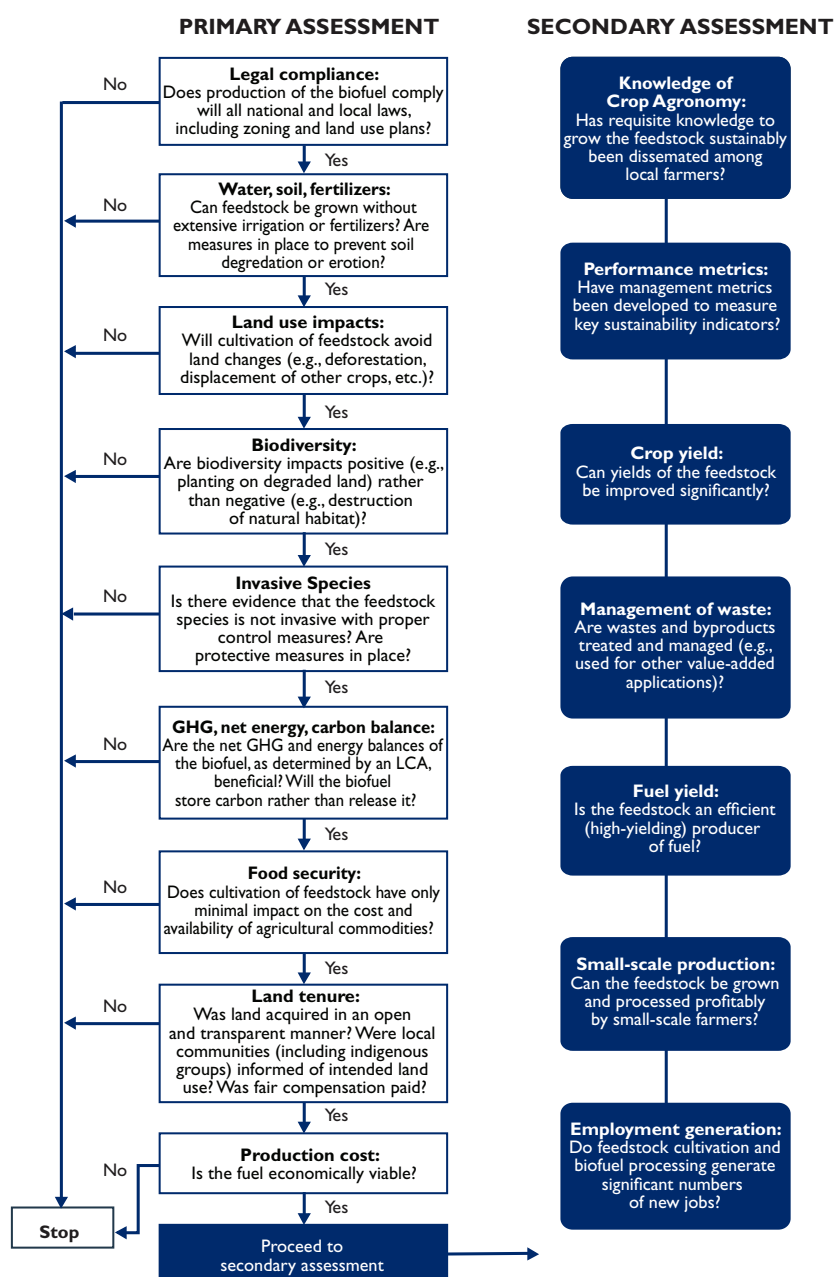
as investors—both private and local government—who consider allocating funds to a feedstock plantation or a biofuels processing facility are in need of a structured decision-making framework that specifically addresses the potential pitfalls of biofuels development, in Asia as well as elsewhere. With this in mind, the diagram below offers a simple but intuitive methodology that can serve as a principal guideline toward reaching a sensible decision on the sustainability of individual biofuels development projects.

The decision tree shown in **Figure 25** is based in part on a similar framework developed by the World Bank in collaboration with the World Wildlife Fund (World Bank/WWF, 2008). Embedded in the decision tree are a set of fundamental criteria and decision factors that must be taken into consideration before investing resources or political capital in biofuels development.

The decision tree is two-tiered. The first tier, labeled Primary Assessment, consists of a simple flow chart that lists the most crucial criteria and presents them in a simple question format. An affirmative answer to each question allows progress to the next step in the flow chart, whereas a negative answer leads to outright rejection of the proposed biofuels project. The criteria in the Primary Assessment are thus similar to the “must haves” suggested by the World Bank’s scorecard. Successful completion of the Primary Assessment indicates that the proposed biofuels project or policy measure fulfills the most fundamental environmental, economic, and social issues identified in this report.

Thereafter, one may proceed to the Secondary Assessment. Listed here are several other decision factors that address a variety of issues concerning the management of biofuels projects, such as yield improvement, legal compliance, and working conditions. These issues also merit careful consideration, especially with respect to planning and management of plantation or processing facilities. However, they are not included in the initial assessment because they are not unequivocal. In other words, failure to satisfy individual secondary criteria need not disqualify a biofuels project altogether. Because they entail mostly managerial issues, the secondary criteria may be more readily controllable by the company or government agency sponsoring the project. Moreover, some secondary criteria

FIGURE 25. Biofuels Decision Tree



that are not met by the proposed project may be mitigated by positive aspects of the project, leading to acceptable tradeoffs in the outcomes of biofuels development.

The decision framework offered here is only a preliminary assessment tool. In most cases, planning for a sustainable and profitable biofuels development will require a thorough and technically detailed assessment of all likely impacts.

While a comprehensive review of the various assessment tools available to analysts and decision-makers is beyond the scope of this report, the reader may want to refer to a valuable compilation of such tools published by the International Union for Conservation of Nature and Natural Resources (IUCN) (Keam and McCormick, 2008). IUCN's findings are summarized briefly in **Table 24**.

Table 24. Technical Tools for Sustainable Biofuels Production

Production Aspect	Tool		Description
Life Cycle Assessment (LCA)	Greenhouse Gases, Regulated Emissions, and Energy use in Transport Model (GREET)	Argonne National Laboratory	LCAs like GREET are used to assess the impacts of the full feedstock-to-fuel pathway, taking into consideration local ecological effects, overall energy and GHG balances of production and consumption of the biofuel, and energy and material flows of production equipment. See: www.transportation.anl.gov/modeling_simulation/GREET/
Other Impact Assessments	Bioenergy Impact Analysis (BIAS)	FAO	Uses existing GHG, land, and water tools to assess impacts of different bioenergy production systems.
Water Resources	Downstream Response to Imposed Flow Transformations (DRIFT)	Southern Waters	A four-module data management tool designed to describe the biophysical consequences of different future flow scenarios. See: www.southernwaters.co.za/downloads/drift.pdf
	Water and Nature Initiative (WANI)	IUCN	A handbook on environmental flows, providing a framework for determining and implementing sustainable environmental flows. See: www.iucn.org/about/work/programmes/water/wp_resources/wp_resources_toolkits/
	Aquastat	FAO	A global database on water and agriculture. See: www.fao.org/nr/water/aquastat/dbases/indexes.stm
	CropWat	FAO	A decision support tool to help agronomists design and manage appropriate crop irrigation systems. See: www.fao.nr.water
	Global Water Tool	WBCSD	Simplifies datasets such as Aquastat and enables businesses to assess their current and future water footprints. See: www.wbcsd.org/web/watertool.htm
Forestry	GRASS GIS QGIS	Various	Tools for monitoring forest landscapes, assessing changes, and modeling potential outcomes of different interventions. See: grass.osgeo.org , www.qgis.org
	STELLA	Isee Systems	A multi-layered model used to assess impacts of different development projects on forests. See: www.cifor.cgiar.org/conservation/_ref/research/research.2.1.htm
Ecosystem Restoration	Landscape Outcomes Assessment Methodology (LOAM)	WWF	Helps those working on landscape level projects to “measure, monitor, and communicate the nature and extent to which a landscape is changing over time with respect to a small number of agreed conservation and livelihood outcomes.” See: www.panda.org/news_facts/publications/index.cfm?uNewsID=120980

Production Aspect	Tool	Developed by	Description
Protected Areas and Biodiversity	High Conservation Value Forests (HCVF)	Forest Stewardship Council (FSC)	Part of a forest certification process; specifies six types of high conservation value. See: hcvnetwork.org/resources/global-hcv-toolkits
	Planning principles, frameworks and guidelines	IUCN	A tool for planning nationally coherent systems of protected areas, identifying key biodiversity areas, categorizing protected areas, managing protected areas, evaluating effectiveness of protected area management, and ensuring equitable involvement by indigenous and local communities in protected areas.
Threatened Species	Red List of Threatened Species	IUCN	A comprehensive inventory of the global conservation status of plant and animal species. See: www.iucnredlist.org
Invasive Species	Database	Global Invasive Species Programme (GISP)	Recommended actions for consideration by those developing biofuels, with a list of potentially invasive species that are being considered as biofuels feedstocks. See: www.gisp.org
	Database	Invasive Species Specialist Group (ISSG)	A database of invasive species. See: www.issg.org/database/welcome
	Pest Risk Analysis (PRA) Pest Risk Management (PRM)	European and Mediterranean Plant Protection Organization (EPPO)	Tools to determine whether a pest should be regulated and what measures should be taken against it. See: www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRA_intro.htm
Food Security	Bioenergy and Food Security (BEFS)	FAO	Uses FAO's Quicksan tool for modeling bioenergy potential to 2050, coupled to the COSMIO agricultural trade model, to build a picture of food security and bioenergy potential trade-offs. See: www.fao.org/NR/ben/befs/
Climate Adaptation	Community-based Risk Screening Tool - Adaptation & Livelihoods (CRiSTAL)	IUCN IISD SEI Intercooperation	A project planning and management tool designed to help project planners and communities integrate risk reduction and climate change adaptation into community-level projects. See: www.iisd.org/security/es/resilience/climate.asp
	Assessment and Design for Adaptation to climate change: a Prototype Tool (ADAPT)	World Bank	Ranks project activities by their sensitivity to current and projected climate and in the future will also include spatial elements such as hazard maps, crop yield maps, and current land use maps which will improve spatial planning. See: go.worldbank.org/AWJKT60300
Certification and Standards	Principles & criteria	RSB, RSPO, RTRS, FSC	Comprehensive certification processes and sustainability criteria for biofuels and specific feedstocks. See: cgse.epfl.ch , www.rspo.org , www.responsiblesoy.org , www.fsc.org

SECTION 10

CONCLUSIONS

This report examines the prospects for sustainable development of biofuels in Asia. It presents a comprehensive evaluation of the environmental, economic, social, and technological impacts of biofuels production in Asia, from the various feedstocks, technologies, and production systems that are currently being deployed in Asia, or have been identified for near-term deployment. Following this, a modeling analysis using country-specific data on land availability, feedstock yields, and assumed technology trajectories was conducted to develop estimates of the total potential production volumes of various biofuels in each of the focus countries. These estimates were then compared with the mandates or quantitative targets that have either been set or proposed in the focus countries to evaluate the extent to which these can be met. Finally, the report identifies policy guidelines and advisory needs for national governments, and a menu of priority actions that can form the focus of technical assistance by USAID.

Based on the above research and analysis, this report recommends a significant deviation from the conventional approach to biofuels development, which focuses on development of large-scale biofuels operations to meet a portion of domestic transport energy demand and to also produce biofuels for export. Such large-scale operations typically require significant subsidies and can often cause negative social and environmental impacts.

Experience demonstrates that large-scale biofuels production is often not a cost-effective option for improving energy security, creating jobs, or reducing GHGs. In addition, there are significant water, land, and food supply constraints that limit the large-scale expansion of biofuels production. A major finding of this report is that first-generation biofuels on a small, decentralized scale may make the greatest contribution to helping countries achieve their energy, development, and environmental priorities. There are certain conditions under which large-scale biofuels operations are sustainable; however, it will take careful planning and oversight on the part of regulators,

in coordination with local actors, to ensure that biofuels production does not compromise food security, biodiversity, or local livelihoods.

KEY FINDINGS

This report is designed to address three broad questions, for which the primary conclusions and recommendations of this report are presented below.

POTENTIAL FOR BIOFUELS TO REPLACE FOSSIL FUELS IN TRANSPORT

1. Do any of the biofuels that can be produced in Asia have the potential to replace fossil fuels as a sustainable energy source and simultaneously reduce net GHG emissions?

Large-scale production of biofuels is unlikely to make a significant contribution to Asia's future transport energy demand. By 2030, biofuels will account for only an estimated 3-14 percent of the total transport fuel mix. This assumes the rapid expansion of high-yielding first-generation biofuels crops on underutilized land, as well as the rapid commercialization and scale-up of cellulosic ethanol production from agricultural residues. Thailand has the highest potential for biofuels to replace transport fuel, and the country may be able to displace about 14 percent of its total fuel demand with biofuels by 2030. It is estimated that India and Indonesia may be able to displace about 12 percent and 11 percent, respectively, of their transport fuel demand with biofuels by 2030. Both the Philippines and Vietnam are each expected to be able to displace roughly 8 percent of their total transport fuel demand with biofuels. It is expected that China may offset 6 percent of its transport fuel demand with biofuels by 2030. At the low end, Malaysia's biofuels production potential is relatively small—at just 3 percent of total transport fuel demand—and this is attributable to a lack of available land for expansion, and a limited availability of crop residues.

The ability to achieve national ethanol and biodiesel mandates varies by country. Based on a medium-growth scenario for transportation fuel demand, all the focus countries, except for Indonesia and the Philippines, are expected to achieve their ethanol blending targets. However, only Indonesia, Malaysia, and the Philippines will meet their biodiesel blending targets (see **Tables 14** and **15** in **Section 5**). In all the focus countries except Indonesia and Malaysia, diesel demand in 2030 is expected to be significantly higher than gasoline demand.

Many biofuels have limited GHG and net energy benefits. Net energy is the balance between energy inputs and energy outputs in the production of one unit of fuel. The GHG balance of a biofuels refers to the net amount of GHGs emitted during the biofuel's life cycle relative to that of fossil fuels. The extent of net energy and GHG benefits varies by feedstock, the location where the feedstock is grown, and the fuel production process, including the use of co-products and wastes. Biofuels with net energy values below those of fossil fuels (1.2 MJ of fossil fuel inputs will produce 1 MJ of energy output) provide greater energy benefits compared to fossil fuels.

Table 25 below shows results for various biofuels feedstocks when produced under best case conditions (see Section 6.1.1 for the full results of the life cycle analysis). Generally speaking, *ethanol produced from non-irrigated sugarcane grown on existing croplands or degraded land*, with efficient use of co-products and wastes, has the most favorable net energy and GHG savings, making it one of the best crops for ethanol production in Asia, where conditions allow. *Ethanol produced from sweet sorghum grown on degraded land* with minimal fertilizer and water inputs also has favorable net energy and GHG balances. *Cellulosic ethanol* also provides a favorable energy balance and a good GHG balance.¹ However, *grain-based biofuels systems* in Asia, under current conditions, result in negative or low net energy and GHG savings, mostly because of high water and fertilizer demands (e.g., corn). When biofuels production results in the replacement of native vegetation, generally the result is greater GHG emissions than those of fossil fuels.

Biodiesel produced from oil palm provides the best net energy and GHG benefits, but only when its cultivation

does not involve land conversion and where there is full utilization of co-products and wastes. *Biodiesel produced from jatropha planted on degraded land* can also provide good net energy and GHG benefits over fossil fuels. *Coconut-based biodiesel* produced under optimal conditions can also provide benefits compared to fossil fuels, with a good net energy balance and GHG savings. The performance of *sweet sorghum* and *jatropha* is based on pilot projects and preliminary assumptions about commercial-level yields.

Most large-scale biofuels production systems are not economically viable without extensive subsidies and are subject to boom and bust cycles. Asian biofuels, while cost-competitive with biofuels from other regions, are expensive relative to fossil fuels. In Asia, production costs for the same feedstock show significant variation between countries, but ethanol from molasses and biodiesel from oil palm and waste oil tend to have the lowest production costs. The profitability of biofuels production systems is highly volatile, given high variability in both input costs and the cost of the substitute (fossil fuels). This exposes producers to significant risks. Therefore, effective utilization of co-products and wastes can be crucial to the profitability of biofuels producers. Subsidies and incentives have driven the growth of biofuels in Asia to date, and they will continue to be required in the future to ensure financial viability. Market entrants will have to undertake a variety of strategies and make careful investments to mitigate ongoing risks. Returns on investments (both public and private) and the rate of market maturation will depend on how government policy, R&D, and operating costs evolve. Analyses of social welfare impacts suggest that biofuels may not be a cost-effective option to reduce GHG emissions or improve energy security, and that by raising food prices, biofuels may in some instances result in negative welfare. Opportunities for expanded trade in biofuels will be limited as long as countries enforce trade barriers and protectionist policies.

The greatest promise for biofuels in Asia lies in decentralizing their production and use. Biofuels can be an important part of countries' strategies to expand access to modern energy for the more than half a billion people in Asia who currently use traditional forms of energy and who, due to their rural location or lack of

¹ Data for cellulosic ethanol is based on feedstocks grown in temperate regions. Feedstocks grown in the tropics are expected to have more favorable yields and therefore would have more favorable net energy and GHG balances.

Table 25. Indicative Ranges of Net Energy and GHG Balances of Biofuels from Selected Biofuels Feedstocks without Land Use Change

CROP	Net Energy Balance *	GHG Savings**
Sugarcane	-0.6 to 0.8 MJ	78-133%
Sweet Sorghum	-0.6 to -0.3 MJ	67-133%
Cellulosic Ethanol	-0.2 to 0.4 MJ	67-111%
Corn	0.4 to 1.2 MJ	11-56%
Oil Palm	-0.3 to 0 MJ	122-156%
Jatropha	-0.5 to 0.4 MJ	100 -144%
Coconut	-0.1 to 0.4 MJ	56-86%

Source: IFEU, 2008

*By way of comparison, the net energy balance of fossil fuels is 1.2 MJ of fossil fuel inputs to produce 1 MJ of energy output. Therefore, biofuels with net energy balances of <1.2 MJ produce net energy savings compared to fossil fuels.

** GHG savings are relative to fossil fuels

Note: These estimates are drawn from various studies that use diverse assumptions. The results are intended to allow relative rather than exact comparisons. Full life cycle analysis results are presented in Section 6.1.1.

market power; buy fossil fuels at significantly above-market prices. Decentralized energy production systems, when managed by community-level organizations, can help to support rural livelihoods, ameliorate local soil and water quality problems, and—to the extent that they avoid forest loss and displace fossil fuels—reduce GHG emissions. Biofuels developed for use in rural Asia could therefore have a greater impact on social welfare, compared to the use of biofuels primarily for transport in urban areas. Several small-scale pilot initiatives are underway in South and Southeast Asia using feedstocks such as jatropha, pongamia, and oil palm for decentralized production. The preliminary results are promising.

CONDITIONS FOR SUSTAINABLE DEVELOPMENT OF BIOFUELS

2. Under what conditions should the above biofuels be produced, distributed, and consumed to avoid threats to biodiversity conservation; food security; impacts on fuel prices, smallholders, and rural livelihoods; and other economic, social, and environmental concerns?

This report provides some guidelines and parameters for the conditions under which biofuels can be grown

and produced sustainably. In general, biofuels should be produced in a way that minimizes the use of land, water, fertilizers, and fossil energy, and does not worsen the quality of air, water, and soil. The focus should be on biofuels feedstocks and practices that do not do any of the following: compete with food production; result in the conversion of native forests or vegetation; compromise labor rights or indigenous rights; or exclude the participation of smallholders. The following factors need to be considered to ensure that biofuels development is sustainable and does not result in significant negative environmental or social impacts.

Sustainable biofuels policies are needed to safeguard food security.

Most analyses of global food prices have concluded that the demand for biofuels, among other factors, contributed to higher food prices from 2005 to 2008. However, the magnitude of the influence is subject to debate. Biofuels may have had an impact on food prices in Asia, but to a lower extent than in other regions. Ethanol produced from corn and cassava, and biodiesel produced from oil palm may have had an impact on the price of food, feed, and edible oils, respectively. Notwithstanding the recent slump in the demand for, and prices of, food commodities, it is likely that the resumption of economic growth and the underlying trends of increasing population and affluence

in Asia will lead to renewed competition between food and fuel, putting net food-importers and food-buying households at risk. The immediate impacts of high food prices can be mitigated through appropriately designed and targeted safety nets. In the medium- to long-term, strategies to ensure food security include: (1) intensifying food production and enhancing yields in existing croplands; (2) restricting biofuels crops to marginal lands not used for food crop production; and (3) increasing reliance on non-food-based and cellulosic ethanol feedstocks.

The environmental impacts of biofuels depend greatly on the type of production system, location, and land cultivation practices. As with other forms of commercial agriculture, the expanded production of biofuels feedstocks can threaten land and water resources as well as biodiversity. Growing first-generation biofuels on croplands or marginal lands using business-as-usual agricultural practices will exacerbate soil erosion, increase nitrate- and phosphate-related water pollution, and cause a decline in biodiversity. The conversion of “new” lands, such as grasslands and forests, presents a significant threat to biodiversity and should therefore be avoided at all costs, particularly in Indonesia, where large tracts of primary rainforest may be slated for biofuels plantations.² Large-scale production of biofuels increases the demand for fresh water—a resource that may face future shortages in many Asian countries. This is a particular concern in China and India. Countries in Southeast Asia are likely to experience water shortages to a lesser extent; however, regional and local shortages may still prove to be a significant concern.

The cultivation of grain-based feedstocks tends to result in higher associated environmental impacts than oil seeds, oil palm, sugarcane,³ and perennial crops. Non-food feedstocks fare better. Sweet sorghum, due to its low demand for water and nutrients, has relatively low impacts, as do jatropha and second-generation feedstocks, owing to their perennial nature and low water and nutrient requirements. Biofuels cultivation can avoid significant environmental impacts through the adoption of agricultural best practices at every stage of production—including no-till farming, advanced fertilizer

and water application techniques, and efficient water and nitrogen use. In addition, the cultivation of biofuels feedstocks should be predicated on the use of polycultures (including native species), rotational diversity, and retention of natural areas as wildlife habitats and corridors. The removal of residue from annual cropping systems to produce cellulosic ethanol should also be limited to prevent the loss of soil carbon and to manage soil erosion.

On balance, switching from fossil fuels to biofuels may benefit local air quality in Asia. It is difficult to predict the cumulative impact on air quality in Asia from a large-scale switch to biofuels for transport. If land clearing and vegetation burning could be largely avoided (and there are significant caveats about the ability to do so), the primary impacts would result from the differences in tailpipe pollutant emissions of biofuels versus fossil fuels. A switch from fossil fuels to biofuels will result in reductions in sulfur oxides (SO_x), particulates, and carbon monoxide (CO). However, biofuels, especially biodiesel, have higher nitrogen oxides (NO_x) emissions than fossil fuels—by as much as 70 percent—depending on the feedstock. Emissions of NO_x combined with volatile organic chemicals and other pollutants can lead to increased ozone (O_3) formation, which is an issue of growing concern in Asia.

Positive social impacts are not a guaranteed outcome from the large-scale deployment of biofuels. While ethanol production systems have a strong tendency toward economies of scale and neglect of smallholder-based production, biodiesel may be better suited to smaller-scale operations. There is widespread evidence across Asia and elsewhere that very often, absent adequate safeguards, the development of biofuels can perpetuate poor labor rights and working conditions, and can threaten lands used by indigenous and marginalized communities. Underutilized lands considered to be favored areas for biofuels expansion are often the only resource accessible to the landless poor, and converting these lands to biofuels production can deny local people access to subsistence farming, fuel wood, and fodder supply. This outcome poses a real threat to the social sustainability of biofuels and can precipitate severe local-

2 Recently the Ministry of Agriculture in Indonesia announced that it plans to remove an existing ban on the conversion of significant amounts of peatlands—which store large amounts of carbon and support biodiversity—into plantations.

3 Except in cases where large amounts of water are used to grow irrigated sugarcane (e.g. India).

level conflicts over resources. National governments and donors can enhance social benefits from biofuels through focused policy interventions. Such measures can include support of smallholders through effective contract farming arrangements and technical assistance, as well as enforcement of labor rights, protection of land rights, participatory processes for indigenous peoples, and implementation of certification systems. It is crucial to achieve a balance between mechanization and the number and quality of new jobs created by the biofuels industry.

Smart incentives are needed to promote biofuels.

With the exception of Brazilian ethanol, unsubsidized biofuels are not yet competitive with fossil fuels.⁴ Experience to date strongly suggests that existing policies and economic incentives for biofuels production have been counterproductive. Most incentive schemes that have been established in Asia are too expensive, and the desired benefits in terms of improved energy security and reduced GHG emissions come at a relatively high cost. It is important for Asian stakeholders to study best practices in biofuels cultivation, business models, and policy frameworks in order to learn from successful examples in other regions of the world. The evidence suggests that extensive support, and subsidies, for current biofuels production systems that ignore more efficient next-generation technologies could lock-in inefficient, unsustainable practices. Instead of relying exclusively on direct subsidies and mandates, a more cautious, yet comprehensive, approach that combines mandates or targets with capital grants, low-interest or guaranteed loans, demonstration projects, technical assistance, and funding for research and development can be a more cost-effective and ultimately successful strategy for promoting biofuels. It will be important for countries in Asia to implement best practices for first-generation biofuels while paving the way for more efficient future technologies.

Support is needed to dismantle trade barriers and establish sustainability certification systems.

Agricultural policies in the form of price supports and regulation of imports and exports, among others, can hamper trade opportunities and distort markets. Currently, countries within the OECD, and also in Asia, have erected

a suite of import tariffs and non-tariff barriers that restrict use of the foreign raw materials or processed biofuels. However, the projected modest surplus in ethanol production in several Asian countries suggests that there is potential for regional trade. It will be important to dismantle trade barriers while simultaneously instituting strict quality and sustainability certification systems in order to ensure that trade liberalization does not lead to unsustainable production practices.

An international framework is needed for sustainable standards and certification of biofuels.

An international dialogue on sustainability criteria and the development of transparent and harmonized standards and certification schemes is currently under way through the Roundtable on Sustainable Palm Oil (RSPO), the Roundtable on Sustainable Biofuels (RSB), and other forums. These platforms will provide an important framework to guard against unsustainable production of biofuels in the future. To ensure that these standards are effectively adopted and enforced, it will be important for smallholders and other stakeholders in developing countries to receive the necessary technical assistance to be able to comply with these schemes. Also, given the projected growth in domestic demand for biofuels in Asian countries, it will be important for certification efforts to focus on both domestic and export markets.

Decision-making under uncertainty. The uncertainty surrounding the environmental, social, and economic viability of biofuels makes it difficult for decision-makers to assess the usefulness of biofuels and to make appropriate choices on how to structure biofuels policies. Policymakers and investors who consider allocating funds to a feedstock plantation or a biofuels processing facility are in need of a structured decision-making framework that addresses the potential pitfalls of biofuels development in Asia. With this in mind, the decision tree presented in this report (see Section 9) offers a framework for guiding decisions on individual biofuels development projects. The decision tree is two-tiered and includes a primary and secondary assessment. Successful completion of the primary assessment indicates that the proposed biofuels project or legislation addresses environmental, economic, and social

⁴ Brazil has eliminated direct subsidies for ethanol produced from sugarcane and achieved significant cost reductions because over the past three to four decades, Brazil has had a sustained program to promote an effective biofuels production. Brazil has developed a highly-efficient production system that uses especially high-yielding varieties of sugarcane, which is transported using ethanol, and bagasse (a co-product of sugarcane) is burned for process energy.

issues. The secondary assessment covers issues that a project developer needs to consider in order to improve the overall performance and competitiveness of the project.

FUTURE PRIORITIES FOR BIOFUELS DEVELOPMENT

3. What priority interventions by USAID would be most useful in promoting the sustainable production and marketing of biofuels in Asia?

Looking forward, international development agencies are well positioned to contribute to the sustainable development of biofuels in Asia. The findings contained in this report highlight specific activities that can maximize the impact of sustainable biofuels programs. Program managers with development agencies may want to consider prioritizing the following activities:

Develop a policy framework for biofuels in Asia.

Numerous national-level biofuels policies and incentives have been proposed and implemented in Asia. Once established, subsidies and support structures for biofuels are difficult to dismantle. It will be important for Asian governments to review existing biofuels policies, evaluate their cost-effectiveness with respect to energy security and environmental impacts, and then promote those policies that will bolster long-term sustainability. For example, USAID could convene a regional dialogue on policies that support the sustainable production of biofuels as well as more efficient regional trade in biofuels, when appropriate.

Map land resources. Claims about the extensive availability of land in Asia for biofuels production are often based on gross-scale national maps that divide land into broad classifications, without an adequately detailed survey of the quality of the land, ongoing uses of the land, the number of people living on or dependent on the area, or its conservation value. There is a pressing need for more detailed land resource assessments to identify the availability of marginal lands that are suitable for biofuels expansion. Such assessments include evaluating the local climate and physical characteristics (topography and soils) and use constraints, and identifying environmentally sensitive areas. USAID could establish partnerships with

national governments and other entities including the US National Renewable Energy Laboratory (NREL) and the Asia Pacific Economic Cooperation (APEC) Biofuels Task Force, which are already engaged in gathering data and information on marginal lands and suitable crops in the APEC economies. This work should be undertaken in partnership with local NGOs and civil society actors who are best placed to reflect local socio-economic realities in the analysis.

Support scale-up and regional replication of sustainable, decentralized biofuels projects.

To date, donors and NGOs have focused their efforts on promoting community-based initiatives to grow biofuels feedstocks and on implementing pilot projects to generate power for households. In order to mainstream this approach, it will be necessary to build political commitment at both the national and local levels, and to provide technical assistance to overcome commercial and technology barriers. USAID could support the replication and scale-up of the best efforts, by: (1) establishing cooperatives, marketing associations, and coordinated supply into larger production facilities; (2) supporting small-scale financing arrangements and carbon finance options; and (3) providing technical assistance to address challenges relating to the small-scale processing of biofuels, and the use of various vegetable oils and fuels in engines and generators.

Support agronomy research and crop improvement.

The rate at which non-food crops, such as jatropha and pongamia, and cellulosic ethanol feedstocks (e.g., grasses and fast-growing trees) are commercialized will depend on how quickly Asian countries can conduct growth trials, gain an understanding of their agronomy and yield potential, and tailor production systems to maximize yields under local growing conditions. In the US, the Department of Energy (US DOE), along with its affiliate laboratories and partner universities, is undertaking the bulk of the research on biofuels feedstock development. In Asia, several national agencies that have broad experience with research in agronomy and improvement in food crops have not yet made a similar foray into supporting the development of biofuels feedstocks. USAID could facilitate US-to-Asia and Asia-to-Asia research partnerships and

technology transfer⁵ in association with key regional entities such as the International Rice Research Institute (IRRI) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which also have an interest in this area.

Support development of regional environmental standards and certification schemes. International standards, performance guidelines, and certification schemes for biofuels, such as RSPO and RSB, are still being developed, USAID can play an important role by supporting the development of national and regional standards and protocols within Asia that are consistent with international standards, and by providing technical assistance to smaller actors and decentralized operations to help them comply with the standards.

Support technology transfer on cellulosic ethanol. Given the advantages of cellulosic ethanol over first-generation biofuels, it will be important to facilitate the transition to second-generation technologies in developing countries using the tools of technology transfer, demonstration, and deployment. Current research, development, demonstration, and deployment (RDD&D)

efforts under way in the US (e.g., US DOE Biomass and Biofuels Program) could be transferred to Asia through public-private partnerships, demonstration projects, and technology transfer initiatives. Technology forums and networks can also facilitate the sharing of research findings, best practices, and lessons learned among Asia's key research centers and international research bodies.

Technical assistance on life cycle analyses (LCAs). With increased scrutiny of the environmental and net energy impacts of biofuels, LCAs have become an important tool to evaluate biofuels feedstocks and production systems. To date, most LCAs on biofuels have been conducted in the US and the EU. Only a handful of LCA studies have been carried out for Asian feedstocks and locations. Technical assistance to build the institutional capacity of Asian stakeholders on LCA techniques, followed by development of LCAs for various Asian feedstocks and growing conditions, could provide a strong basis for Asian policymakers, investors, project developers, and community organizers to make informed decisions regarding options for sustainably scaling up the production of biofuels.

⁵ In February 2009, the US and India signed a Memorandum of Understanding to establish a framework of cooperation covering scientific, technical, and policy aspects of the production, conversion, use, distribution and marketing of biofuels in a sustainable manner. One element of this collaborative effort will be the use of biofuels feedstock obtained from non-edible oil seeds grown on wastelands with the active involvement of local communities. The production and development of quality planting material and especially crops with high sugar content (such as sugarcane, sweet sorghum and cassava) will be emphasized. The scope of cooperation also encompasses advanced conversion technologies for first-generation biofuels; emerging technologies for second-generation biofuels; and electricity production projects based on a decentralized approach.

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COUNTRY PROFILES

I.I CHINA

INTRODUCTION

China consumed over 79 billion liters of gasoline and 158 billion liters of diesel in 2008. During this time, automobile use in China increased on average by 11.8 percent annually. This rapid growth has led to serious environmental problems.

As part of its strategy to meet the growing demand for energy, China seeks to expand energy efficiency initiatives and the use of alternative, domestically produced fuels. Biofuels form an important part of this strategy. China's stated objectives for developing biofuels include:

- improving of the welfare of rural citizens;
- strengthening China's energy security and reducing oil dependence; and
- mitigating emissions that have a negative impact on the environment.

The biofuels program in China began in early 2000 with the launch of the Henan province ethanol pilot production plant, followed by the setting of ethanol standards. To ensure development of biofuels, the central government regulates both the supply and demand for biofuels, and has limited ownership of production facilities.

ETHANOL PRODUCTION

China is the world's third-largest producer of ethanol. Maize has been the primary feedstock for China's fuel ethanol production, followed by wheat. Total ethanol production was estimated to be 6,686 million liters in 2008, of which an estimated two-thirds to three-quarters was consumed by the pharmaceutical and beverage industries (F.O. Licht, 2007 in OECD, 2008).

Against rising prices and inflation, as well as a declining land area for producing grains, the government re-evaluated the use of maize for ethanol production. Presently, the

government's official policy is to utilize non-grain feedstocks, in particular sweet potato, cassava, and sweet sorghum, which are grown on non-arable and marginal lands. The government estimates the crops could be grown on 116 million hectares of marginal lands that are unsuitable for producing grains.

Subsidies were made available for producing ethanol from cellulose, sweet sorghum, and cassava as a means to reduce the percentage of corn and wheat diverted to ethanol production. Ultimately, China plans to move to cellulosic ethanol production using biomass and crop residues, which are in sufficient supply. China's four large grain-based ethanol plants are also in the process of converting to production based on non-grain feedstocks. China National Cereals and the Oils and Foodstuffs Corp. (COFCO) are investing 50 million Yuan (US\$6.5 million) in building a cellulosic ethanol pilot plant.

BIODIESEL PRODUCTION

China's biodiesel industry is in the early stages of development. Small manufacturing units from the private sector dominate the biodiesel industry. Total production has grown more than eight-fold since 2004. Current feedstock is derived primarily from used cooking oil, acid oil, and animal fat. It is estimated that about 3 million tonnes of waste oil and grease are produced in China annually. Dozens of biodiesel projects are under construction or in the planning stages, with a cumulative capacity of more than 3 million tonnes per year. OECD-FAO estimates China's biodiesel production in 2007 was 355 million liters.

In the long term, China plans to pursue non-edible feedstocks, including jatropha, Chinese pistachio, and Chinese tallow tree. Jatropha is abundant in southwest China, and the intention is to develop large-scale plantations; however, these areas (Sichuan, Yunnan, Guizhou, etc.) contain ecologically sensitive and biodiverse forests; thus, plantation locations and policies will need to be carefully considered. Over the next few years, China

expects to plant about 800,000 hectares of jatropha. Jatropha could potentially become a major cash crop for farmers in southwest China, but this will largely depend on farmers being able to contract directly with jatropha processors and energy companies. Despite these plans, uncertainty over the successful expansion of jatropha will be a constraining factor for the biodiesel industry.

POLICIES AND EXPANSION PLANS

In 2001, the State Council launched the Fuel Ethanol Program, leading to the establishment of the four main ethanol plants. Incentives such as tax credits, VAT refunds, and fiscal subsidies were made available to ethanol producers. No supports were introduced for the biodiesel industry.

The aim of the revised National Plan is to increase fuel ethanol production to 10 million tonnes (almost 12.7 billion liters) and biodiesel to 2 million tonnes (almost 2.4 billion liters) per year by 2020. Accordingly, E10 will be available in more provinces by 2010, and possibly E20 and E85, as well as B5 or B10 by 2020.

The government's overall policy is to move toward technologies and feedstocks that do not compete with arable land or use grain as feedstock. Feedstocks with generally more positive social and environmental impacts include sweet sorghum, sweet potato, cassava, and cellulosic biomass. No new corn-based ethanol plants are expected to be approved. China is considering additional subsidies and tax breaks for demonstration projects using non-grain feedstock and plantations growing non-food crops.

The Renewable Energy Law (which came into effect in January 2006) set out definitions of biofuels and confirms China's commitment to encouraging their use. It establishes a Renewable Energy Fund to assist with biofuel technology R&D, standards development, demonstration projects, research and assessment of raw materials, information dissemination, and domestic equipment manufacturing. Inclusion of biofuels in the National Renewable Energy Industry Development Guide Directory would enable manufacturers and cultivators of energy crops to get discounted loans and tax incentives for equipment.

THE ROAD AHEAD

A significant constraint for China's biofuels industry going forward will be feedstock shortages and limited supplies of waste vegetable oil for biodiesel. It is cost-prohibitive to import vegetable oils for biodiesel production, so biodiesel production will be constrained until additional feedstock sources are developed. For China's biofuels program to be successful in the long run, it will also be critical to address subsidy inequalities with petroleum-based fuels and land conflicts in proposed expansion areas. A strategy should be developed to promote biofuels for decentralized applications and marginal lands should be identified for community plantations. To maximize effect in the transport sector, these efforts should be combined with energy efficiency improvements in vehicle fleets and moves toward market-based prices for transport fuels.

1.2 INDIA

INTRODUCTION

In India, interest in biofuels has grown dramatically over the last few years, prompted by concerns over energy security. The primary driving factor is increasing oil imports due to rising transport fuel demand. India consumed 11 billion liters of gasoline and over 47 billion liters of diesel in 2008.¹

Biofuels present an opportunity to promote sustainable development while offsetting rising demand for conventional energy sources. While the primary objective in blending biofuels with petrol-based fuels is to reduce the financial cost of the national oil import bill, the other significant advantages of biofuels include environmental and air quality benefits, the greening of wastelands, and the creation of new employment opportunities.

Food security, in particular, is a national priority for India. Consequently, India cannot afford to promote the use of cereal grains for ethanol production and the use of edible oil for biodiesel production. India is one of the world's leading importers of vegetable oil, and food grain production has been relatively stagnant in recent years, resulting in net wheat imports in 2006. Therefore, biofuel policies target the use of waste and non-edible feedstocks for biofuel production.

¹ India imports over 70 per cent of its petroleum. The Indian Planning Commission estimates that the country's demand for petrol will rise from 9.3 million tons in 2006–2007 to 16.4 million tons by 2017 (MoPNG, 2008).

ETHANOL PRODUCTION

India has been operating an ethanol program for a number of years. Nine provinces currently have an official blending obligation of 5 percent ethanol.² India is one of the world's leading producers of sugarcane – a total of 5.04 million hectares of land are currently under sugarcane cultivation, and there are no plans for sugarcane expansion.

In India, ethanol is produced from sugar molasses. The industry is encouraged to supplement the production of ethanol from molasses by producing ethanol directly from sugarcane juice in areas with surplus sugarcane. Total ethanol production – for both fuel and other purposes – reached an estimated 2.5 billion liters in 2008, up from just over 2.1 billion liters in 2004. The government of India has not produced estimates of fuel ethanol. Efforts to produce ethanol from sweet potato, sweet sorghum, and cassava remain at the experimental stage.

BIODIESEL PRODUCTION

Biodiesel production is focused on using non-edible oils from plants, particularly *jatropha curcus*, *pongamia*, other tree-borne oilseeds (such as *karanj*), and animal fats like fish oil. The goal is to encourage the use of wastelands, non-forest land, and other unproductive land for the cultivation of relatively hardy biofuel crops. As biofuel crop production is very labor intensive, its cultivation will also provide additional employment opportunities.

Currently, biodiesel production is small and decentralized, yields are low, and production costs remain high. OECD estimates that biodiesel production was 317 million liters produced in 2008 although country estimates are unavailable (OECD-FAO, 2008). The cost of biodiesel is largely dependent on the choice of feedstock and the size of the production facility. According to officials at the Ministry of New and Renewable Energy (MNRE), *jatropha* and other feedstocks have been planted on 700,000 hectares of wasteland by several state governments and private entrepreneurs during 2006–2008.³ However, very little data is available on crop survival and growth rates.

POLICIES AND EXPANSION PLANS

The Indian Government's 2006 policy mandating 5 percent ethanol blending has helped boost ethanol consumption in 10 states. No direct financial assistance or tax incentives are available to produce or market ethanol or ethanol-blended petrol. However, the government of India offers subsidized loans to sugar mills for setting up an ethanol production unit (i.e., 2 percent below market rate, up to a maximum of 40 percent of the project cost). Starting in 2006, the Ministry of Petroleum and Natural Gas announced a biodiesel purchase policy in which oil companies would purchase biodiesel and blend it with high-speed diesel (HSD) at a 5 percent blending ratio. However, the government did not provide any direct financial incentives for biodiesel production or for plant and facility investments. As a result, India's biodiesel production remains small.

Updating its biofuel policies, in September 2008, the government of India approved a national policy that aims to raise the proportion of biofuels from 5 to 20 percent in both gasoline and diesel fuels by 2017 using non-edible plant sources. However, this policy has yet to be signed into law. Targeted feedstocks are ethanol from plant wastes, chiefly sugarcane molasses for ethanol, and biodiesel produced from non-edible oilseed crops such as *jatropha* for biodiesel.

To avoid competition with food crops, the policy supports increasing biodiesel plantations on community, government-owned, and forest wastelands, but not on fertile, irrigated lands. The policy also details incentives for growers of biofuel crops: removing taxes and duties on biodiesel, setting a minimum “support” price for buying biodiesel oilseeds from growers, and a minimum purchase price of bioethanol from oil marketing companies. These should ensure adequate returns to both crop growers and oil makers. Different levels of a minimum support price for oilseeds have already been declared by certain states. The prescribed blending levels will be reviewed and moderated periodically as per the availability of biodiesel and bioethanol.

2 The nine states are Maharashtra, Tamil Nadu, Uttar Pradesh, Punjab, Karnataka, Andhra Pradesh, Bihar, Haryana, and Gujarat

3 The states involved include Chhattisgarh, Madhya Pradesh, Rajasthan, Orissa, Andhra Pradesh, Uttarakhand; most of the states also have dedicated institutional arrangements to promote biofuels.

Current production is enough to meet the 5 percent ethanol blend mandate; however, to meet even a 10 percent mandate, current production facilities would need to be expanded. There is considerable debate about how much land is available and where to expand biofuels production. To meet the 5 percent national biodiesel target, 2.19 million hectares of biodiesel feedstocks will need to be planted, far more than the 700,000 hectares of jatropha claimed to be planted from 2006 to 2008. The Ministry of Agriculture reports that there are a total of 50 million hectares of uncultivated and fallow land potentially available for biofuel plantations. Analysis from the Department of Land Resources estimates that roughly 13.4 million hectares are available for jatropha plantations on land identified as marginal or fallow, which could potentially yield 15 million tons of oil annually (Science and Development Network, 2008).⁴ However, these problems haven't stopped states from pursuing aggressive programs.

However, problems have persisted, even at plantations where jatropha plants have borne fruit. Although the Indian Express (John, 2008) reported success in Chhattisgarh state, where 400 million jatropha saplings were planted on more than 155,000 hectares of fallow land in the last three years, there are no data on either the survival of saplings or seed production. Where the trees have borne fruit, various departments and local agencies, are waiting for guidelines on collection and sale of seeds.

THE ROAD AHEAD

Discussions with officials indicate that there are two key constraints in the development of biofuels. The first relates to administrative controls that some states have placed on free movement of biofuels across state borders, and restrictions at the district level, which make it very difficult for biofuels to be transported across state and district borders. The second key constraint arises from differential tax structures at the state level, in spite of biofuels being a renewable source of energy. There are still no clear guidelines on the issues of biofuels being given the same treatment as other renewable sources, which do not have any state or central taxes. This is because of the fact that states also have a key role to play in terms of land for plantations, setting up of processing facilities, and for final sale to consumers. This is unlike the case of all petroleum

fuels, where the central government has the sole authority to make policies across the country.

Key policy issues that need to be addressed include the development of a pricing scheme and a financial framework, providing R&D support for seed development and reducing production and processing costs, and identifying and supporting Clean Development Mechanism (CDM) opportunities. The release of lands identified as available for jatropha cultivation by the state governments remains an obstacle as states are still waiting for guidelines on the collection, sale, and processing of jatropha seeds.

The Indian biofuel industry continues to face other challenges. Fast population growth, rising income levels, increasing demand for agricultural products, and lagging government policies have put the country's land and water resources under enormous strain. The growing emphasis on expanding biofuel production capacity, primarily through the augmentation of ethanol output based on irrigated sugarcane, is expected to put further pressure on water resources. It might also lead to the diversion of land from food crops to sugarcane. The National Biofuel Policy is currently under revision to meet the gaps and shortcomings that have been identified.

Considering the slow rate of progress in biodiesel production and the fact that several policy issues still need to be resolved, it is unlikely that India's biofuels targets will be achieved. Analysis by the UN Conference on Trade and Development (Gonsalves (2006) concluded that India will not be able to reliably produce ethanol from sugarcane, and that difficulties in procuring oilseeds and the lack of infrastructure could hamper biodiesel production in the near to medium term. Therefore, it is expected that India will have to import both bioethanol and biodiesel to meet its targets (ibid).

I.3 INDONESIA

INTRODUCTION

Indonesia's fossil reserves of oil, gas, and coal are its primary sources of energy, with 48 percent of primary energy originating from oil. Despite Indonesia's status as a major petroleum producer, it became a net petroleum oil

⁴ Other sources have reported that roughly 40 million hectares of degraded, marginal land is available for biofuels. This highlights the conflicts over how much land is truly available in India for biofuels cultivation.

importer in 2004. In 2007, the total final gasoline and diesel demand was roughly 17.6 and 11.1 billion liters, respectively.

It was not until after global oil prices soared and the country became a net oil importer that the government of Indonesia focused on the importance of biofuels as an alternative energy source. Oil prices and decline in petroleum reserves and production forced the government to reduce or lift fuel price subsidies and start to look at biofuels as a viable alternative energy source.⁵ For the private sector, production of biofuels was not seen as economically viable until after the government changed the fuel price subsidies in late 2005. Indonesia now sees biofuels as one of the key instruments to accelerate economic growth, alleviate poverty, and create employment opportunities, while at the same time mitigating greenhouse gas emissions.

ETHANOL PRODUCTION

Currently, fuel ethanol in Indonesia is produced from sugarcane molasses. Indonesia has about 5.5 million acres dedicated to sugarcane production, and several companies want to expand their plantations. The country is among the top 10 sugarcane producers in the world with about 30 million tonnes per year. Ethanol producers face several challenges, particularly, since alcohol is strictly prohibited in Indonesia for religious reasons, ethanol sales are heavily regulated with high tariffs and taxes.

Total ethanol production in Indonesia was about 212 million liters in 2008 (OECD-FAO, 2008). Fuel ethanol installed capacity, as of late 2008, was about 215 million liters. The official goal is to produce close to 4 billion liters by 2010 (OECD-FAO, 2008; APEC, 2008). Most sugar mills in Indonesia are less efficient state-owned enterprises, and many still use Dutch colonial technology. Indonesian government officials and industry are also looking at cassava as an alternative ethanol feedstock.

BIODIESEL PRODUCTION

The main biodiesel feedstock in Indonesia is crude palm oil (CPO) due to a well-established industry and potential for expanded production. Indonesia is the world leader in palm oil production. In 2008, Indonesia's biodiesel production capacity was estimated to be 2.9 billion liters annually. In that year, the government of Indonesia estimated biodiesel

production to be 1.5 billion liters, but OECD-FAO places the total for 2008 at 753 million liters. Total oil palm plantation area was estimated to be more than 6 million hectares.

The central government has established laws and regulations guiding biofuels expansion, including a ban on further forest destruction, but local governments exercise greater control and it is suspected these laws are not always followed. In mid-February, Indonesia's Agricultural Ministry announced that it would lift the moratorium on palm oil plantations on peatlands. Indonesia is considering jatropha and coconut oil in its next phase of expansion in order to avoid competition with food-based CPO. Because the productivity of palm oil is so high, however, jatropha and coconut cultivation for biofuels may remain small without strong expansion programs. At this time, the government appears to be focusing on the use of jatropha in remote areas where electricity is very expensive.

POLICIES AND EXPANSION PLANS

Currently, the government's targets for ethanol and biodiesel are to produce 17.3 billion liters of fuel ethanol and 29 billion liters of biodiesel by 2025. The Indonesia government has set blending mandates at 10 percent for biodiesel starting in 2010, and 20 percent for ethanol starting in 2015. In order to reach these targets, current production must be vastly expanded.

Indonesia faces the difficult task of trying to meet its mandates by producing biofuels sustainably and without increasing forest destruction. The government has developed a set of land classification maps outlining land considered available for government biofuel expansion plans for jatropha, palm oil, sugarcane, and cassava. (See Annex 5 for maps). One key issue is that much of the land that has been identified as suitable for biofuels plantation is high conservation-value primary rainforest or peatland. In particular, all four crops are to be planted on Borneo and Sumatra, which are habitats for a number of endangered species, such as orangutans.

The government provides special fiscal incentives on top of investment guarantees and protections to encourage foreign and national investments. In late February of 2009,

⁵ Based on an assumed world crude oil price of US\$57 per barrel, the government allocated IDR 54 trillion (US\$6 billion) to fuel subsidies in 2006 alone (ESMAP, 2006).

the government announced an Indonesian Rupiah (IDR) 33 trillion subsidy for biofuels. The subsidy is worth IDR563 to IDR572, based on a crude oil prices between US\$45 to US\$60. The subsidy is provided as long as biofuels prices are higher than fossil fuel prices. Value-added tax reductions for businesses and excise duty cuts are also available for biofuels users. In 2007, the government announced an interest rate subsidy of IDR 1 trillion for farmers growing biofuels crops (i.e., jatropha, oil palm, cassava, and sugar cane). The government is considering additional upstream fiscal and non-fiscal incentives, including tax holidays and extended land concession rights.

THE ROAD AHEAD

Energy security, job creation (particularly in rural areas), building on existing strengths in the agricultural sector, and development of new export opportunities were among the top reasons motivating the Indonesian government to promote biofuels development. Biofuels are intended to provide energy to remote rural settlements, which currently depend on long, costly supply lines. Nevertheless, even with record-high oil prices in 2008, biofuels remained more expensive to produce than petroleum fuels, adding to the government's fuel-subsidy burden. Additionally, Pertamina (the state-owned oil company) reported losses of IDR 360 billion (US\$40 million) from 2006 to June 2008 due to biofuel blending (GSI, 2008).

Indonesia could become a world leader in biodiesel exports, depending on movements in world palm oil prices and how environmental sustainability of palm cultivation is addressed. The government is, however, continuing with ambitious plans to develop a large, subsidized domestic biofuels industry, despite its recent lessons in the environmental and social costs of biofuels and the social and political difficulties in reforming petroleum fuel subsidies.

I.4 MALAYSIA

INTRODUCTION

Malaysia's energy requirements are expected to grow annually by 4.8 percent until 2030 to three times their 2005 levels. Over this period, energy for transport is projected to rise at 5.3 percent annually from the 15.7 billion liters of gasoline and diesel used in 2008.

In 2005, the Malaysian government introduced ambitious biofuel policies to begin profitably transforming its key agricultural product (palm oil) into biodiesel. The principal aims were to expand the market for palm oil, improve energy security, and create a new export industry. The main concerns for expanding biodiesel production in Malaysia are land availability as well as associated sustainability and biodiversity issues.

ETHANOL PRODUCTION

As the primary focus is on palm oil, production of bioethanol in Malaysia is still in its infancy. Malaysia produced an about 70 million liters of ethanol in 2008, though this does not separate out ethanol for fuel purposes (OECD-FAO, 2008). Until 2007, there was almost no consumption of bioethanol in Malaysia; In 2008, consumption rose to upwards of 4 million liters. There is an opportunity for ethanol production from the oil palm biomass (part of it left unutilized), but this technology has yet to be commercialized and there are no immediate plans to pursue cellulosic technology. The government has no mandate for ethanol and has major expansion plans.

BIODIESEL PRODUCTION

Oil palm is the primary crop for biofuels in Malaysia. Eleven percent of the country's total land area (about 62 percent of the economy's agricultural land) is devoted to palm oil, although only about 10 percent of it is diverted for fuel (APEC, 2008).

Biodiesel production began in 1982 with a pilot plant based on palm oil. In response to a large increase in biodiesel demand from the European Union (EU), Malaysia's production of biodiesel grew from 86 million liters in 2005 to 443 million liters in 2008 (OECD-FAO). It should be noted that the Malaysian government estimates that biodiesel production in 2008 was significantly lower (i.e., 201 million liters) than the OECD-FAO estimate. Part of the reason for the discrepancy could be that OECD made projections based on capacity while in actuality, 2008 saw production contract significantly. By 2008, 92 new biodiesel projects had been approved, but only eight of those had produced biodiesel in 2008 (approximately 10 percent of approved new production capacity). Many plants suspended operations due to high feedstock prices in 2008; some plants closed. Assuming no further closures or cancellations, total production capacity is expected to reach approximately 2.7 million tons in 2009.

Since Malaysia initially subsidized end-user prices of petroleum transport fuels – totaling Malaysian Ringgit (RM) 25 billion in 2008 – biodiesel was seen as a promising avenue to reduce both the consumption of petroleum and the government's subsidy burden. However, biodiesel in 2008 was estimated to cost around RM0.67 (US\$0.20) per liter more to produce than petroleum diesel when palm oil is RM3000 per metric ton and crude oil is US\$115 per barrel. Replacing petroleum diesel with biodiesel would therefore worsen the government's subsidy burden, rather than improve it. Replacing five percent of petroleum diesel with biodiesel could add RM395 million (US\$122 million) per year to this subsidy bill, at the above mentioned prices (GSI, 2008b).

POLICIES AND EXPANSION PLANS

In August 2005, the Malaysian Government launched the National Biofuel Policy (NBP), which created a national B5 mandate. The implementation of this policy was unsuccessful due to soaring palm oil prices and the fact the original equipment manufacturers (OEMs) voided the warranty on engines using biofuel blends. The domestic mandate was abandoned in favor of producing CPO for the export market. Now that the export market is restricted, Malaysia has reinstated the B5 mandate (as of February 2009), which is to be fully implemented by 2010. A B5 mandate would require Malaysia to consume around 560,000 million liters.

To continue to encourage CPO exports, the Malaysian Palm Oil Board (MPOB) has been promoting Malaysian palm oil internationally by demonstrating the health benefits of consuming palm oil, addressing non-tariff barriers (e.g., countering environmental and consumer perceptions), promoting different uses of the product (e.g., development of palm biodiesel and palm polyurethane), and improving palm oil's brand image. Malaysia is supporting the adoption of Roundtable on Sustainable Palm Oil (RSPO) certification and has strict rules on deforestation. In 2008, Malaysia's United Plantations shipped the first batch of RSPO-certified palm oil to Europe.

THE ROAD AHEAD

Malaysia presently has strong regulations aimed at protecting tropical forest, especially on the peninsula of Malaysia. However, increased demand in the future may increase pressures on forests. Increased demand could be

met through increased productivity of existing plantations and conversion of land to new plantations. The B5 mandate would require an additional 130,000 hectares of land – 3 percent of the current 4.2 million hectares currently under cultivation. In contrast, the analysis in Section 5.4 of the main report shows that a B5 mandate would require 323 million liters of biodiesel.

The majority of new Malaysian oil-palm developments are in the states of Sarawak and Sabah on the island of Borneo. These state governments have a great deal of autonomy and it appears that, in some areas at least, environmental impact assessments are not rigorously performed. Many Malaysian firms are also operating in the Indonesian provinces of Kalimantan and Riau on the island of Borneo, which have high rates of conversion of forest to oil-palm, and less exacting governance structures. Both for environmental and social reasons (conflicts with indigenous peoples and poor labor rights), measures to certify sustainable production will become increasingly important in order to supply the environmentally conscious markets of the OECD. Certification and good governance are important to ensure social and environmental goals are not comprised by future biofuels development.

1.5 PHILIPPINES

INTRODUCTION

The Philippines' indigenous fossil fuel reserves are relatively small. The transport sector consumed 4.3 billion liters of gasoline and 5.8 billion liters of diesel in 2008. Biofuels form part of the strategy to reduce energy imports. The hope is to eventually achieve self-sufficiency. Sugarcane and coconut are the preferred Philippine biofuel feedstocks. Fuel ethanol production only began in 2008 with the introduction of an ethanol mandate. B2 and E10 are already available nationwide. The Philippines is actively pursuing jatropha as an alternative feedstock for biofuels production.

ETHANOL PRODUCTION

Sugarcane is the primary source for ethanol production in the Philippines. It is considered a reliable feedstock due to its well-established farming technologies and highest yield per hectare compared to other feedstocks. Additional ethanol feedstocks under consideration are sweet sorghum and cassava. Currently, the OECD estimates total ethanol production to be about 105 million liters

per year, while the Philippines Department of Energy estimates about 39 million liters of fuel ethanol were produced in 2008.

Uncommon to the rest of Asia, fuel ethanol is made directly from sugarcane, while non-fuel ethanol uses sugarcane molasses. One fuel distillery started production in 2008, the other main distillery started commercial production in early 2009. E10 blends have been selectively available since 2008 but have utilized imported ethanol, because of local shortfalls. An E5 mandate took effect as of February 2009. It is expected that local companies will need to continue to import fuel ethanol to meet the mandate.

BIODIESEL PRODUCTION

Domestic biofuels production is currently limited to coco methyl ester (CME), also known as coco-biodiesel.⁶ In 2008, there were 11 biodiesel facilities with an output capacity of 348 million liters per year, which exceeds the volumes mandated by the Biofuels Act. That excess provides a potential export opportunity for biodiesel producers (APEC, 2008). However, OECD-FAO estimates actual biodiesel production in 2008 was 211 million liters. The Philippines DOE estimates biodiesel consumption was 78.8 million liters in 2008, with an increase to 163.9 million liters expected in 2009.⁷

Additional potential biodiesel feedstocks under consideration in the Philippines are jatropha and palm oil. The government plans to launch a large program to cultivate jatropha seeds on around two million hectares of what it describes as unproductive and idle public and private lands nationwide. It is likely, however, that some of these lands are already being used for other purposes. Larger companies, mostly foreign-owned, are using an integrated jatropha plantation and processing model, as some are looking primarily to export. There are more than 10 Philippines Department of Energy accredited biodiesel processing plants that can use jatropha as feedstock. The Philippines National Oil Company Alternative Fuels Corporation together with the Department of Science and Technology are currently conducting performance testing of a commercial jatropha oil expelling facility that can easily be set up in areas where jatropha feedstock are available in

commercial quantities. Currently, a few pilot plantations are growing oil palm.

POLICIES AND EXPANSION PLANS

Under the Biofuels Act of 2006, the government implemented a mandatory blending of 1 percent biodiesel in all diesel-fed vehicles in May 2007, which increased to 2 percent biodiesel blend by February 2009. An economy-wide mandatory blending of 5 percent bioethanol in all gasoline-fed vehicles will start in February 2009 to reach 10 percent by February 2011. A National Biofuels Board (NBB), an inter-agency body headed by the DOE Secretary, will oversee implementation of the country's National Biofuels Program. Compliance with the mandate will be determined by the scheduled construction and completion of the appropriate number of plants. Incentives to encourage the production and use of biofuels include exemptions from wastewater charges and from specific taxes for raw materials (coconut, sugarcane, jatropha, cassava, etc.). Favorable loan policies from banks for biofuel investors and producers are also available.

To meet the ethanol mandate the Philippines must expand its current total 344,700 hectares of sugarcane. The Sugar Regulatory Administration (SRA) has identified an additional 237,748 hectares of available land, mostly in Mindanao, that can be tapped to produce fuel ethanol (APEC, 2008).

THE ROAD AHEAD

The Philippines hopes to position itself as a leading biofuels producer in the region. The main challenges facing the industry are the availability of feedstock and processing facilities to meet demand set by national mandates. The University of the Philippines in Los Baños is leading research and development efforts, by studying the use of biodiesel derived from jatropha, and of bioethanol from cassava and sweet sorghum. The Philippines National Oil Company Alternative Fuels Corporation (PNOC-AFC) is conducting performance testing of a commercial jatropha oil expelling facility that can be easily set up in areas where commercial quantities of jatropha feedstock is available. In 2007, Ford Philippines opened a manufacturing plant for flexible fuel engines that can run on ethanol blends

⁶ The Philippines is one of the largest producers of coconut oil in the world, second after Indonesia. It produces approximately 1.4 billion liters per year, of which 80 percent is exported.

⁷ In comparison, the analysis in Section 5.4 of the main report estimates that the Philippines would require 119 million liters to meet a B2 mandate.

of up to 20 percent. Production of engines from the facility is expected to be sufficient for export to other ASEAN countries. The plant's opening may accelerate the adoption of biofuels in the economy (APEC, 2008). However, nationally, infrastructure to supply E5 or E10 is weak and feedstock production, processing facilities and supply stations will need to be scaled up to expand ethanol consumption.

1.6 THAILAND

INTRODUCTION

Thailand continues depend on energy imports, particularly oil, which accounted for 57 percent of the energy supplied to the economy. Gasoline and diesel consumption were 4.7 and 16.7 billion liters, respectively. Of 51 million hectares of land, 27 percent is forest and 45 percent is dedicated to agriculture. With a strategic view to reducing dependency on energy imports, Thailand has implemented various policies to accelerate the development of biofuels.

ETHANOL PRODUCTION

Ninety percent of ethanol production is from molasses, the rest from cassava. Production is expected to gradually shift to a greater percentage of cassava over the next 5–10 years. OECD-FAO estimates total ethanol production in Thailand to be close to 408 million liters in 2008. The Thai Board of Investment estimates the total capacity of ethanol production in Thailand to be about 584 million liters per year.

Feedstock pricing is the main issue for ethanol processing plants. Ethanol producers in Thailand are not producing fuel at capacity because growers receive an insufficient purchase price. The Thai government's policy is to purchase ethanol at the Brazilian export price (also known as the Brazilian parity). Because Thailand's ethanol feedstock and fuel production costs are higher than Brazil's, feedstock producers sell their primary stock to food producers, so only leftover molasses and cassava are used for ethanol.

BIODIESEL PRODUCTION

Biodiesel production in Thailand was estimated to be 48 million liters in 2008 according to OECD-FAO. However, Thailand's Department of Energy and Energy Efficiency (DEDE), reports 2008 biodiesel production was closer to 400 million liters. The Thailand board of

investment estimates installed capacity to be 876 million liters annually. Production is from a mixture of waste cooking oil and palm oil, both of which are in limited supply. Given the current low utilization of installed capacity due to lack of feedstock supply, Thailand will need to encourage biodiesel consumption by its citizens, in order to meet the B5 mandate.

Palm oil cultivation has steadily increased from 385,000 hectares in 2004 to 503,000 hectares in 2007 and is expected to grow to 680,000 hectares in 2012. Efforts are ongoing to increase yields. A primary driver in the expansion of palm oil production has been an increase in procurement prices for palm crops by the government. However, reports indicate that, after export and domestic use, very little is left for biodiesel production. Thailand has banned the import of palm oil but it plans to offer an additional 1.6 million hectares for cultivation by 2023.

Thailand also plans to gradually introduce jatropha as a substitute for palm oil and has put in place about 16,000 hectares for jatropha cultivation. However, these fields are still in the pilot phase. Even though jatropha has lower yields, it has certain advantages, such as the ability to grow in areas with low rainfall, and in degraded, fallow, and other wastelands of low fertility in arid and semi-arid areas. This has the advantage of not competing with fertile land that should be used for food crops.

POLICIES AND EXPANSION PLANS

The Thai government has ambitious plans to displace imported fuel with renewable energy sources within the next five years. It introduced a B2 mandate in February 2008, aiming to have B2 available nationwide by the end of 2008, which would require the production of approximately 420,000 metric tons of biodiesel per year. Future targets mandate B5 by 2011 and B10 by 2012. For ethanol, the government aims for 3 million liters to be consumed daily by 2011, increasing to 9 million liters per day by 2022. A minimum blend of E10 was announced for 2008, but has been delayed until 2011, due to consumer resistance, primarily because ethanol blends are not suitable for many older cars. This delay highlights the changing state of mandates and policies in Thailand, which will no doubt continue to fluctuate.

Policy incentives for ethanol include soft loans, “build-own-operate” privileges for fuel ethanol plants, and an excise tax holiday for ethanol blended in gasohol. The government has set gasohol prices at 2.0-5.0 baht/liter less than regular and premium gasoline to encourage its use. The government has also mandated all its fleet to be fueled with gasohol. An excise tax reduction for cars that can use gasoline containing at least 20 percent ethanol has been effective since January 2008; this reduces the price of such cars by THB10,000 (\$US300).

THE ROAD AHEAD

Thailand has adopted ambitious strategies for its biofuels program. Obstacles to increasing production and usage of biofuels in Thailand include a lack of confidence on the part of end-users, lack of adequate biodiesel feedstocks and purchase prices too low to encourage production. Increased yields may improve the amount of feedstocks available but pricing issues remain the largest obstacle.

1.7 VIETNAM

INTRODUCTION

The economic transformation and rapid economic development in Vietnam has resulted in an accompanying rapid increase in fuel demand. Gasoline and diesel consumption was about 4.4 and 7.6 billion liters, respectively. Beyond 2010, Vietnam expects to transform from a net energy-exporting economy to a net-importing economy, which would require new policies to ensure an adequate supply. Therefore, the government's chief objective for biofuels is as a substitute for petroleum. Biofuels production in Vietnam is a nascent industry but is expected to grow rapidly, since the 2007 government decision to promote biofuels as part of a diversified energy supply.

ETHANOL PRODUCTION

Currently, fuel ethanol production is very small. The existing ethyl alcohol industry currently uses cane molasses and cassava as feedstock. Sugarcane production has been steadily growing during the past six years, at about 16 million metric tons annually, while cassava production has grown rapidly from 2 million metric tons in 2000 to about 7.5 million in 2008 (APEC, 2008). Estimates show that Vietnam has been producing ethanol for a number of years and production is likely to continue growing at a rapid pace.

Total ethanol production is estimated by the OECD to be 164 million liters in 2008, although the government's estimate for total ethanol was 316 million liters in 2007. E5 blends are available, though not nationwide.

Vietnam is looking to advance its bioenergy program by constructing commercial-scale ethanol plants using different biofuel feedstocks. One facility, to be constructed by Itochu Corporation (Japan), will utilize cassava chips and have an estimated annual production capacity of 100 million liters. Another planned plant, to be constructed by a partnership between Vietnam's Bien Hoa Sugar Company and Singapore's Fair Energy Asia Ltd, will have an annual ethanol production capacity of 50 million liters. Both plants are expected to come online in 2009, and other plants are expected to be operational in 2010.

In addition to expanded use of sugarcane, cassava, and rice, dedicated energy crops, such as elephant grass, and biomass residues are seen as opportunities for the future. An estimated 47 million metric tons of agricultural and woody residues could be used in cellulosic ethanol production (APEC, 2008).

BIODIESEL PRODUCTION

Biodiesel is currently not produced in commercially significant amounts, although biodiesel production from catfish oil is a growing cottage industry. Potential biodiesel feedstocks in Vietnam include animal fat (catfish oil), used cooking oil, rubber seed, and jatropha oil.

Various initiatives are being undertaken to produce biodiesel from catfish oil and used vegetable oil. The Vietnamese catfish processor and exporter Agifish is building a 10,000 metric ton per year biodiesel facility, claiming it can produce one liter of biodiesel per kilogram of catfish oil. The Ho Chi Min City Research Center for Petrochemical and Refinery Technology has successfully developed technology to produce biodiesel from waste cooking oil. About 73,800 metric tons of used cooking oil were produced in 2005, which would produce approximately 33,000 metric tons of biodiesel. A current pilot project produces about two metric tons of biodiesel per day (APEC, 2008).

The Institute of Applied Materials & Science and the Institute of Tropical Biology in Ho Chi Min City are

researching biodiesel production from rubber seed oil and other oil-bearing crops (including jatropha). The Department of Agriculture and Rural Development has a jatropha trial plantation of 5,000 hectares. In one example, sites have been selected for jatropha development, in partnership with Eco-Carbene, and biodiesel production is expected to start at that site in 2010. Eco-Carbene's objective is to reach 60,000 tons of biodiesel production per year at full capacity.

POLICIES AND EXPANSION PLANS

In November 2007, the government approved a biofuel development plan through 2015, with a vision through 2025, to produce different kinds of renewable energy and to partly replace traditional fuels. As part of PetroVietnam's biofuel plans, 35,000 hectares of land have been set aside to cultivate high-yielding crops that will lead to ethanol production.⁸

The Biofuel Master Plan has set the following targets:

- By 2010, 100,000 tons of E5 and 50,000 tons of B5 (to meet 0.4 percent of domestic fuel demand);
- By 2015, 5 million tons of E5 and B5 combined (to meet 1 percent of domestic fuel demand);
- By 2025, 1.8 million tons of bioethanol and biodiesel (to satisfy 5 percent of domestic fuel demand).

Vietnam has strong potential for biofuel development because of its sugarcane, jatropha, cassava, and castor-oil trees. These crops are considered ideal for biofuel

production. In particular, Vietnam has large cassava production potential, which is reported to thrive in marginal soils and with low agricultural inputs. Studies have also found that cassava is an efficient biofuel feedstock, with a strong energy balance. Residues can be used as animal feed or for energy.

Fiscal incentives provided for biofuels include tax exemptions for investors in biofuels production, import tax reduction for biofuel production equipment, and leasing and tax incentives on land leasing are proposed for the future.

THE ROAD AHEAD

Vietnam is pursuing its renewable energy resources because of the high cost of fossil imports needed to meet demand. The Ministry of Science and Technology has indicated that, at current prices, the country may not be able to afford importing more than 15–17 million metric tons per year of fuel, which is not adequate to meet that demand. Vietnam has commissioned alternate energy sources like solar and wind power, but output, so far, has been low.

Current efforts focus on feedstock selection, research and development, and creating favorable conditions for the development of biofuels, by promoting investment through tax incentives and low-interest loans. The main priorities for biofuels research and development in Vietnam are to increase crop productivity and develop advanced conversion technologies to take advantage of the country's large amounts of cellulosic residues.

8 Crops will be cultivated in the provinces of Vinh Phu, Phu Tho, Yen Bai, Son La, Hao Binh, and Tuyen Quang.

ANNEX 2

LIST OF STAKEHOLDERS CONSULTED IN ECO-ASIA CDCP COUNTRIES

CHINA NGO

EU-China Energy Environment Programme (EEP)

Frank Haugwitz, Renewable
Energy Project Manager
BEIJING

GOVERNMENT

Tsinghua University

Prof. Dehua Liu,
Director of the Department of
Chemical Engineering
BEIJING

University of Science and Tech- nology Beijing

Prof. Heinz-Peter Mang, Manager, Insti-
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ANNEX 3

LIFE CYCLE CALCULATION TABLES FOR NET ENERGY AND GHG BALANCES OF VARIOUS FEEDSTOCKS

KEY NOTE ON CALCULATIONS IN THE TABLES

In the tables below, expenditures include all modules of the production chain from land use change to biofuel use. Credits include processes in which co-products are used to produce other products or services (e.g., bagasse residues for energy generation or glycerin for soap production). The balance subtracts credits from expenditures and also subtracts energy from fossil fuels used in the process; the fossil fuel expenditure subtracted for both petrol and diesel is 1.2 MJ PE/MJ fuel.

All balanced are in relation to the baseline of fossil fuel, calibrated at "0." The more negative the number, the better the environmental performance (more favorable energy and GHG balance) compared to fossil fuel. A positive number indicates the energy inputs to a particular biofuel are greater than the energy output or more GHG emissions are released in the production chain that are saved, compared to fossil fuel. A balance of "0" indicates an equivalent ratio of inputs to outputs and net GHG emissions to fossil fuels. Land-use change is not a factor in net energy balance since land conversion is not equal to an energy input. However, LUC is differentiated in relation to net GHG emissions (**Tables A3** and **A4**).

Table AI. Primary Energy Demand Of Selected Types Of Bioethanol

PRODUCTION OF BIOETHANOL	MJ PE / MJ fuel	
	Worst	Best
Sugar cane (Brazil)		
Expenditures	1.0	0.6
Credits	-0.2	-1.2
Balance	-0.4	-1.8
Corn		
Expenditures	1.4	0.6
Credits	-0.2	-0.2
Balance	0.0	-0.8
Sweet sorghum		
Expenditures	0.9	0.1
Credits	-0.3	-0.4
Balance	-0.6	-1.5
Cellulosic ethanol		
Expenditures	0.4	0.4
Credits	0.0	-0.6
Balance	-0.8	-1.4

Table A2. Primary Energy Demand of Selected Types Of Biodiesel

PRODUCTION OF BIOETHANOL	MJ PE / MJ fuel	
	Worst	Best
Palm		
Expenditures	0.4	0.3
Credits	-0.4	-0.6
Balance	-1.2	-1.5
Jatropha		
Expenditures	0.7	0.5
Credits	-0.3	-1
Balance	-0.8	-1.7
Coconut		
Expenditures	0.5	0.3
Credits	-0.1	-0.4
Balance	-0.8	-1.3

Table A3. GHG Emissions of Selected Types of Bioethanol

PRODUCTION OF BIOETHANOL		Greenhouse Gas Emissions	
Sugar cane – Brazil - no land use change		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	40	50
Credits	g CO ₂ equiv./MJ fuel	-20	-80
Balance	g CO ₂ equiv./MJ fuel	-70	-120
Sugar cane – Brazil - natural land		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	50	50
Credits	g CO ₂ equiv./MJ fuel	-20	-80
Balance	g CO ₂ equiv./MJ fuel	-60	-120
Sugar cane – Thailand (Nguyen et al., 2007a, 2007b)		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	150	14
Credits	g CO ₂ equiv./MJ fuel	-35	-35
Balance	g CO ₂ equiv./MJ fuel	32	-111
Corn		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	100	60
Credits	g CO ₂ equiv./MJ fuel	-20	-20
Balance	g CO ₂ equiv./MJ fuel	-10	-50
Cassava – Thailand (Nguyen et al., 2007a)		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	46	
Credits	g CO ₂ equiv./MJ fuel	-33	
Balance	g CO ₂ equiv./MJ fuel	-77	
Sweet Sorghum – dense vegetation		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	90	60
Credits	g CO ₂ equiv./MJ fuel	-20	-50
Balance	g CO ₂ equiv./MJ fuel	-20	-80
Sweet Sorghum - scarce vegetation		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	90	20
Credits	g CO ₂ equiv./MJ fuel	-60	-50
Balance	g CO ₂ equiv./MJ fuel	-60	-120
Cellulosic Ethanol		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	30	30
Credits	g CO ₂ equiv./MJ fuel	0	-40
Balance	g CO ₂ equiv./MJ fuel	-60	-100

Table A4. GHG Emissions of Selected Types Of Biodiesel

PRODUCTION OF BIODIESEL		Greenhouse Gas Emissions	
Palm - natural forest		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	60	30
Credits	g CO ₂ equiv./MJ fuel	100	90
Balance	g CO ₂ equiv./MJ fuel	70	30
Palm - peat forest		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	1110	870
Credits	g CO ₂ equiv./MJ fuel	-20	-40
Balance	g CO ₂ equiv./MJ fuel	1000	740
Palm - fallow		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	50	30
Credits	g CO ₂ equiv./MJ fuel	-70	-80
Balance	g CO ₂ equiv./MJ fuel	-110	-140
Jatropha - medium vegetation		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	300	130
Credits	g CO ₂ equiv./MJ fuel	-30	-90
Balance	g CO ₂ equiv./MJ fuel	180	-50
Jatropha - no vegetation		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	80	60
Credits	g CO ₂ equiv./MJ fuel	-80	-100
Balance	g CO ₂ equiv./MJ fuel	-90	-130
Coconut (no land use change)		Worst	Best
Expenditures	g CO ₂ equiv./MJ fuel	50	40
Credits	g CO ₂ equiv./MJ fuel	-10	-30
Balance	g CO ₂ equiv./MJ fuel	-50	-80

ANNEX 4

PALM OIL CARBON DEBTS AND REPAYMENT

Table A5. Carbon Debts¹ And Repayment Times Reported In The Literature For Palm Oil

SOURCE	CO ₂ (t/ha) unless noted	TIME	CONVERSION FROM	LOCATION	PAYBACK TIME (in years for CO ₂)
Schmidt (2007)	415	25yrs	Secondary/degraded forest	Malaysia/ Indonesia	51*
Schmidt (2007)	-33	25yrs	Along-alang grassland	Malaysia/ Indonesia	0*
Henson (2004)	27.5/yr		Peat soil	Malaysia/Indonesia	168*
Reijnders & Huijbregts (2008)	745	25 yrs	Non-peaty soils	Malaysia	91*
Reijnders & Huijbregts (2008)	1,832	25 yrs	Peat soil	Malaysia	224*
Hooijer et al. (2006)	73-100/yr†	50 yrs	Peat swamp forest	SE Asia	447-613
Fargione et al. (2008)	610	50 yrs	Lowland tropical rainforest	Malaysia/ Indonesia	86
Fargione et al. (2008)	3,000	50 yrs	Tropical peatland rainforest	Malaysia/ Indonesia	423
Fargione et al. (2008)	6,000	120 yrs	Tropical peatland rainforest	Malaysia/ Indonesia	846
Germer & Sauerborn (2007)	1,454	25 yrs	Tropical peatland rainforest	SE Asia	282
Germer & Sauerborn (2007)	788	25 yrs	Tropical forest (mineral soil)	SE Asia	153
Germer & Sauerborn (2007)	-6	25 yrs	Grassland rehabilitation	SE Asia	0
Danielsen et al. (2008)	760		Rainforest (non-peaty)	SE Asia	84 **
Danielsen et al. (2008)	6,371	long-term equilibrium	Peat forest	SE Asia	692
Danielsen et al. (2008)	-191	at palm maturity	Degraded grassland	SE Asia	10
Verwer et al. (2008)	1,804	50yrs	Tropical peatland rainforest	SE Asia	254
Gibbs et al. (2008) §	6,384	§§	Tropical peat forests	SE Asia	661
Gibbs et al. (2008) §	540	§§	Tropical humid forests	SE Asia	71
Gibbs et al. (2008) §	125	§§	Trop. humid disturbed forests	SE Asia	29
Gibbs et al. (2008) §	-18	§§	Trop. humid woody savannah	SE Asia	15
Gibbs et al. (2008) §	-264	§§	Trop. humid grassland	SE Asia	0
Gibbs et al. (2008) §	-319	§§	Tropical humid degraded land	SE Asia	0
Gibbs et al. (2008) §	-304	§§	Trop. humid annual cropland	SE Asia	0
Gibbs et al. (2008) §	144	§§	Seasonal tropical forests	SE Asia	33
Gibbs et al. (2008) §	-50	§§	Seasonal trop. disturbed forests	SE Asia	11
Gibbs et al. (2008) §	-125	§§	Seasonal trop. woody savannah	SE Asia	2
Gibbs et al. (2008) §	-224	§§	Seasonal tropical grassland	SE Asia	0
Gibbs et al. (2008) §	-279	§§	Seasonal tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	-264	§§	Seasonal trop. annual cropland	SE Asia	0
Gibbs et al. (2008) §	45	§§	Dry tropical forests	SE Asia	21
Gibbs et al. (2008) §	-98	§§	Dry tropical disturbed forests	SE Asia	5
Gibbs et al. (2008) §	-158	§§	Dry tropical woody savannah	SE Asia	-2
Gibbs et al. (2008) §	-238	§§	Dry tropical grassland	SE Asia	0
Gibbs et al. (2008) §	-279	§§	Dry tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	-264	§§	Dry tropical annual cropland	SE Asia	0

Notes:

¹ Carbon Debt (net carbon release) from conversion of habitats to biofuel production. Except for Gibbs et al. (2008), estimates include emissions from land clearing and biofuel production.

* Apportionment and annual repayment based on Fargione et al. (2008)

** Avg. of burnt and non-burnt forests. §Gibbs et al. (2008) only provide estimates of payback time. Carbon debts shown in the table are calculated from information provided in their supplemental material.

§§ The authors do not specify the time period over which emissions are included but rather use estimates of percent carbon lost from soils.

† Soil only.

Table A6. Carbon Debts¹ And Repayment Times Reported In The Literature For Soybean Biodiesel

SOURCE	CO ₂ (t/ha) unless noted	TIME	CONVERSION FROM	LOCATION	PAYBACK TIME (in years for CO ₂)
Fargione et al. (2008)	>280	50 yrs	Tropical rainforest (Amazon)	Brazil	319
Fargione et al. (2008)	33	50 yrs	Cerrado grassland	Brazil	37
Gibbs et al. (2008) §	6,689	§§	Tropical peat forests	SE Asia	12,305
Gibbs et al. (2008) §	878	§§	Tropical humid forests	SE Asia	1,628
Gibbs et al. (2008) §	464	§§	Trop. humid disturbed forests	SE Asia	870
Gibbs et al. (2008) §	330	§§	Trop. humid woody savannah	SE Asia	624
Gibbs et al. (2008) §	84	§§	Trop. humid grassland	SE Asia	169
Gibbs et al. (2008) §	-15	§§	Tropical humid degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Trop. humid annual cropland	SE Asia	0
Gibbs et al. (2008) §	448	§§	Seasonal tropical forests	SE Asia	735
Gibbs et al. (2008) §	254	§§	Seasonal trop. disturbed forests	SE Asia	425
Gibbs et al. (2008) §	183	§§	Seasonal trop. woody savannah	SE Asia	310
Gibbs et al. (2008) §	84	§§	Seasonal tropical grassland	SE Asia	148
Gibbs et al. (2008) §	-15	§§	Seasonal tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Seasonal trop. annual cropland	SE Asia	0
Gibbs et al. (2008) §	349	§§	Dry tropical forests	SE Asia	816
Gibbs et al. (2008) §	206	§§	Dry tropical disturbed forests	SE Asia	490
Gibbs et al. (2008) §	150	§§	Dry tropical woody savannah	SE Asia	366
Gibbs et al. (2008) §	70	§§	Dry tropical grassland	SE Asia	182
Gibbs et al. (2008) §	-15	§§	Dry tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Dry tropical annual cropland	SE Asia	0

Notes:

Except for Gibbs et al. (2008), estimates include emissions from land clearing and biofuel production.

¹ Carbon Debt (net carbon release) from conversion of habitats to biofuel production.

§ Gibbs et al. (2008) only provide estimates of payback time. Carbon debts shown in the table are calculated from information provided in their supplemental material.

§§ The authors do not specify the time period over which emissions are included but rather use estimates of percent carbon lost from soils.

Table A7. Carbon Debts¹ And Repayment Times Reported In The Literature For Sugarcane Ethanol

SOURCE	CO ₂ (t/ha) unless noted	TIME	CONVERSION FROM	LOCATION	PAYBACK TIME (in years for CO ₂)
Fargione et al. (2008)	165	50 yrs	Cerrado woodland	Brazil	17
Gibbs et al. (2008) §	6,659	§§	Tropical peat forests	SE Asia	750
Gibbs et al. (2008) §	849	§§	Tropical humid forests	SE Asia	98
Gibbs et al. (2008) §	435	§§	Trop. humid disturbed forests	SE Asia	51
Gibbs et al. (2008) §	301	§§	Trop. humid woody savannah	SE Asia	36
Gibbs et al. (2008) §	55	§§	Trop. humid grassland	SE Asia	9
Gibbs et al. (2008) §	-44	§§	Tropical humid degraded land	SE Asia	0
Gibbs et al. (2008) §	-29	§§	Trop. humid annual cropland	SE Asia	0
Gibbs et al. (2008) §	419	§§	Seasonal tropical forests	SE Asia	51
Gibbs et al. (2008) §	225	§§	Seasonal trop. disturbed forests	SE Asia	29
Gibbs et al. (2008) §	154	§§	Seasonal trop. woody savannah	SE Asia	20
Gibbs et al. (2008) §	55	§§	Seasonal tropical grassland	SE Asia	9
Gibbs et al. (2008) §	-44	§§	Seasonal tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	-29	§§	Seasonal trop. annual cropland	SE Asia	0
Gibbs et al. (2008) §	316	§§	Dry tropical forests	SE Asia	37
Gibbs et al. (2008) §	173	§§	Dry tropical disturbed forests	SE Asia	22
Gibbs et al. (2008) §	117	§§	Dry tropical woody savannah	SE Asia	16
Gibbs et al. (2008) §	37	§§	Dry tropical grassland	SE Asia	7
Gibbs et al. (2008) §	-48	§§	Dry tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	-33	§§	Dry tropical annual cropland	SE Asia	0

Notes:

Except for Gibbs et al. (2008), estimates include emissions from land clearing and biofuel production.

1 Carbon Debt (net carbon release) from conversion of habitats to biofuel production.

§ Gibbs et al. (2008) only provide estimates of payback time. Carbon debts shown in the table are calculated from information provided in their supplemental material.

§§ The authors do not specify the time period over which emissions are included but rather use estimates of percent carbon lost from soils.

Table A8. Carbon debts^I and repayment times reported in the literature for castor oil

SOURCE	CO ₂ (t/ha) unless noted	TIME	CONVERSION FROM	LOCATION	PAYBACK TIME (in years for CO ₂)
Gibbs et al. (2008) §	6,689	§§	Tropical peat forests	SE Asia	13,947
Gibbs et al. (2008) §	878	§§	Tropical humid forests	SE Asia	1,845
Gibbs et al. (2008) §	464	§§	Trop. humid disturbed forests	SE Asia	986
Gibbs et al. (2008) §	330	§§	Trop. humid woody savannah	SE Asia	707
Gibbs et al. (2008) §	84	§§	Trop. humid grassland	SE Asia	192
Gibbs et al. (2008) §	-15	§§	Tropical humid degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Trop. humid annual cropland	SE Asia	0
Gibbs et al. (2008) §	448	§§	Seasonal tropical forests	SE Asia	1,030
Gibbs et al. (2008) §	254	§§	Seasonal trop. disturbed forests	SE Asia	596
Gibbs et al. (2008) §	183	§§	Seasonal trop. woody savannah	SE Asia	435
Gibbs et al. (2008) §	84	§§	Seasonal tropical grassland	SE Asia	208
Gibbs et al. (2008) §	-15	§§	Seasonal tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Seasonal trop. annual cropland	SE Asia	0
Gibbs et al. (2008) §	349	§§	Dry tropical forests	SE Asia	362
Gibbs et al. (2008) §	206	§§	Dry tropical disturbed forests	SE Asia	217
Gibbs et al. (2008) §	150	§§	Dry tropical woody savannah	SE Asia	162
Gibbs et al. (2008) §	70	§§	Dry tropical grassland	SE Asia	81
Gibbs et al. (2008) §	-15	§§	Dry tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Dry tropical annual cropland	SE Asia	0

Notes:

^I Carbon Debt (net carbon release) from conversion of habitats to biofuel production.

§ Gibbs et al. (2008) only provide estimates of payback time. Carbon debts shown in the table are calculated from information provided in their supplemental material.

§§ The authors do not specify the time period over which emissions are included but rather use estimates of percent carbon lost from soils.

Table A9. Carbon Debts¹ and Repayment Times Reported in the Literature for Corn Ethanol

SOURCE	CO ₂ (t/ha) unless noted	TIME	CONVERSION FROM	LOCATION	PAYBACK TIME (in years for CO ₂)
Fargione et al. (2008)	111	50 yrs	Newly converted grasslands	Central US	93
Fargione et al. (2008)	57	50 yrs	Abandoned cropland (15 yrs)	US	48
Gibbs et al. (2008) §	6,689	§§	Tropical peat forests	SE Asia	4,210
Gibbs et al. (2008) §	878	§§	Tropical humid forests	SE Asia	557
Gibbs et al. (2008) §	464	§§	Trop. humid disturbed forests	SE Asia	298
Gibbs et al. (2008) §	330	§§	Trop. humid woody savannah	SE Asia	213
Gibbs et al. (2008) §	84	§§	Trop. humid grassland	SE Asia	58
Gibbs et al. (2008) §	-15	§§	Tropical humid degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Trop. humid annual cropland	SE Asia	0
Gibbs et al. (2008) §	448	§§	Seasonal tropical forests	SE Asia	289
Gibbs et al. (2008) §	254	§§	Seasonal trop. disturbed forests	SE Asia	167
Gibbs et al. (2008) §	183	§§	Seasonal trop. woody savannah	SE Asia	122
Gibbs et al. (2008) §	84	§§	Seasonal tropical grassland	SE Asia	58
Gibbs et al. (2008) §	-15	§§	Seasonal tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Seasonal trop. annual cropland	SE Asia	0
Gibbs et al. (2008) §	349	§§	Dry tropical forests	SE Asia	281
Gibbs et al. (2008) §	206	§§	Dry tropical disturbed forests	SE Asia	167
Gibbs et al. (2008) §	150	§§	Dry tropical woody savannah	SE Asia	126
Gibbs et al. (2008) §	70	§§	Dry tropical grassland	SE Asia	63
Gibbs et al. (2008) §	-15	§§	Dry tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	0	§§	Dry tropical annual cropland	SE Asia	0

Notes:

¹ Carbon Debt (net carbon release) from conversion of habitats to biofuel production.

§ Gibbs et al. (2008) only provide estimates of payback time. Carbon debts shown in the table are calculated from information provided in their supplemental material.

§§ The authors do not specify the time period over which emissions are included but rather use estimates of percent carbon lost from soils.

Table A10. Carbon Debts¹ and Repayment Times Reported in the Literature for Prairie Biomass Ethanol

SOURCE	CO ₂ (t/ha) unless noted	TIME	CONVERSION FROM	LOCATION	PAYBACK TIME (in years for CO ₂)
Fargione et al. (2008)	6	50 yrs	Newly converted grasslands	Central US	1
Fargione et al. (2008)	0	50 yrs	Abandoned cropland (15 yrs)	US	0

Notes:

¹ Carbon Debt (net carbon release) from conversion of habitats to biofuel production.**Table A11. Carbon Debts¹ And Repayment Times Reported in the Literature for Coconut Oil**

SOURCE	CO ₂ (t/ha) unless noted	TIME	CONVERSION FROM	LOCATION	PAYBACK TIME (in years for CO ₂)
Gibbs et al. (2008) §	6461	§§	Tropical peat forests	SE Asia	4,365
Gibbs et al. (2008) §	617	§§	Tropical humid forests	SE Asia	489
Gibbs et al. (2008) §	202	§§	Trop. humid disturbed forests	SE Asia	216
Gibbs et al. (2008) §	59	§§	Trop. humid woody savannah	SE Asia	120
Gibbs et al. (2008) §	-187	§§	Trop. humid grassland	SE Asia	0
Gibbs et al. (2008) §	-242	§§	Tropical humid degraded land	SE Asia	0
Gibbs et al. (2008) §	-227	§§	Trop. humid annual cropland	SE Asia	0
Gibbs et al. (2008) §	184	§§	Seasonal tropical forests	SE Asia	207
Gibbs et al. (2008) §	-10	§§	Seasonal trop. disturbed forests	SE Asia	76
Gibbs et al. (2008) §	-84	§§	Seasonal trop. woody savannah	SE Asia	25
Gibbs et al. (2008) §	-183	§§	Seasonal tropical grassland	SE Asia	0
Gibbs et al. (2008) §	-238	§§	Seasonal tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	-224	§§	Seasonal trop. annual cropland	SE Asia	0
Gibbs et al. (2008) §	56	§§	Dry tropical forests	SE Asia	116
Gibbs et al. (2008) §	-87	§§	Dry tropical disturbed forests	SE Asia	29
Gibbs et al. (2008) §	-147	§§	Dry tropical woody savannah	SE Asia	0
Gibbs et al. (2008) §	-227	§§	Dry tropical grassland	SE Asia	0
Gibbs et al. (2008) §	-268	§§	Dry tropical degraded land	SE Asia	0
Gibbs et al. (2008) §	-253	§§	Dry tropical annual cropland	SE Asia	0

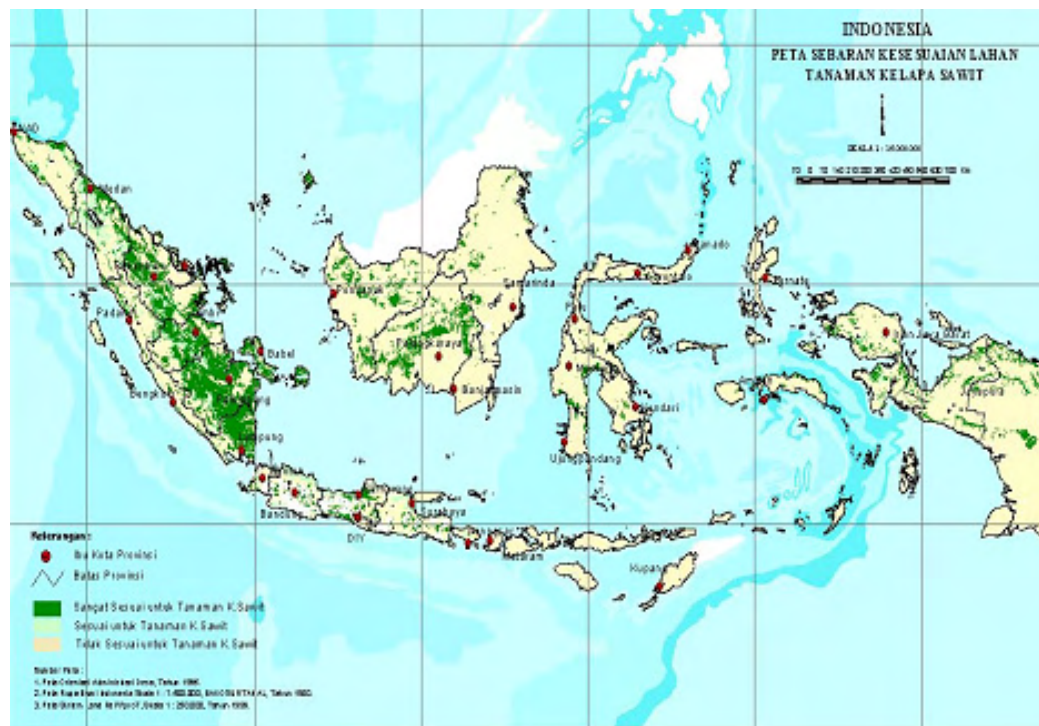
Notes:

¹ Carbon Debt (net carbon release) from conversion of habitats to biofuel production.

§ Gibbs et al. (2008) only provide estimates of payback time. Carbon debts shown in the table are calculated from information provided in their supplemental material.

§§ The authors do not specify the time period over which emissions are included but rather use estimates of percent carbon lost from soils.

MAPS OF LAND PLANNED FOR BIOFUEL FEEDSTOCK EXPANSION IN INDONESIA

FIGURE A2. Land and Climate Compatibility Map for Palm Oil (3 Million Ha)

Source: Ministry of Energy and Natural Resources

FIGURE A3. Land availability for cassava plantation (No land area given)

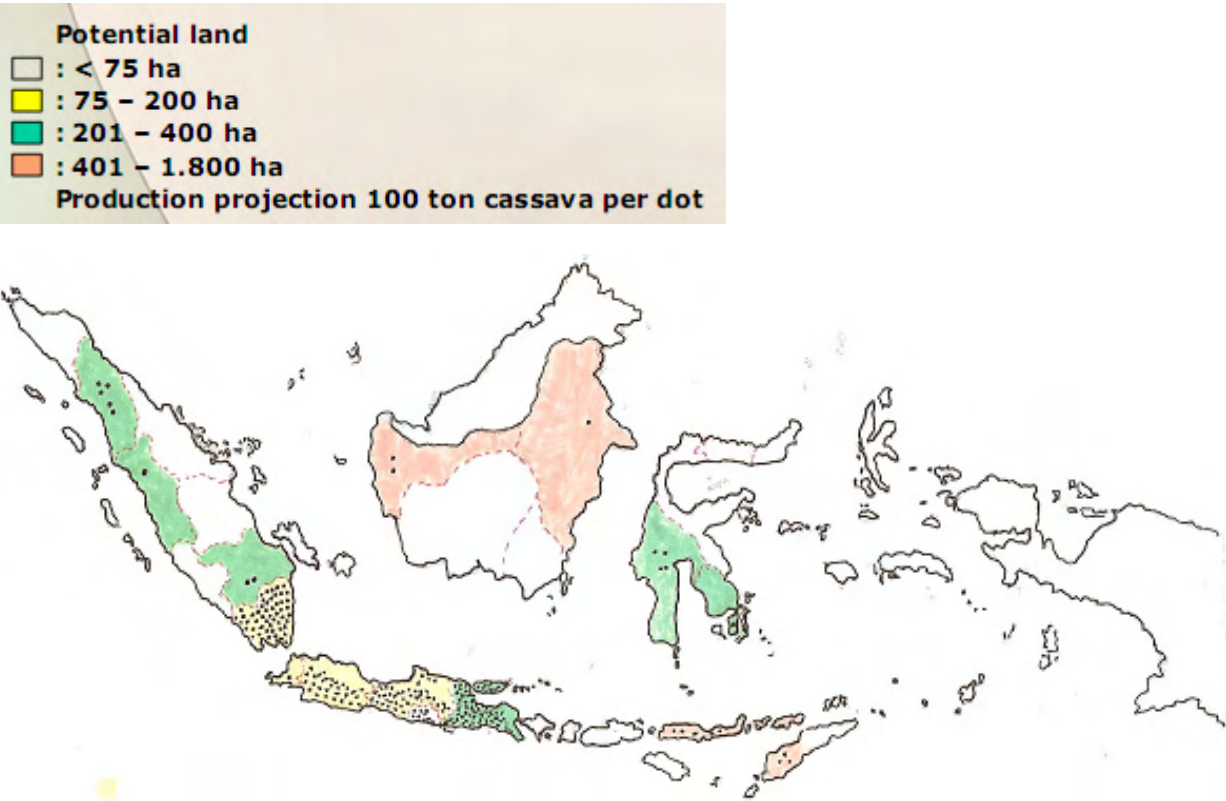


FIGURE A4. Land and Climate Compatibility Map for Sugarcane (0.5 Million Ha)



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