

# Sustainable Bioenergy in Asia:

## Improving resilience to high food prices and climate change



Bioenergy in Asia and the Pacific

Food and Agriculture Organization of the United Nations



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Cover design: Sansiri Visarutwongse  
Compiled by: Atchariya Mata  
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Printed and published in Bangkok, Thailand

© FAO 2012  
ISBN 978-92-5-107291-2

## **Sustainable bioenergy in Asia: Improving resilience to high food prices and climate change**

**Selected papers from a conference held in Bangkok from 1 to 2 June 2011**

**Edited by Beau Damen and Sverre Tvinnereim**



**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS  
REGIONAL OFFICE FOR ASIA AND THE PACIFIC  
BANGKOK 2012**



# FOREWORD

High fossil energy prices and the growing need for more environmentally sustainable energy sources have encouraged many governments in the region to adopt policies to support the development of modern bioenergy sectors. The effect of these policies could be substantial. According to the International Energy Agency, regional bioenergy output – including liquid biofuels – is expected to grow tenfold by 2030.

FAO views this trend as both a significant challenge and an emerging opportunity. Bioenergy developments draw upon many of the same natural and labor resources that underpin the region's food production systems. Increased competition for these resources could lead to higher food prices. Recent experience with high and volatile food prices around the world has shown that changes in food prices disproportionately impact on those communities living close to or below the food poverty line. Large scale bioenergy expansion could also affect the quality and stock of natural resources for food and bioenergy feedstock production depending on the types of resource management techniques employed. Climate change may further complicate this situation by further straining the natural resource base and promoting greater instability in regional food production systems.

However, some bioenergy technologies and systems have been shown to reduce GHG emissions and promote economic development in poor, rural areas. At the community level, bioenergy can improve energy access with flow on benefits for food preparation, health and nutrition. Bioenergy by-products such as bio-slurry and biochar can also invigorate community farming systems by replenishing local natural resources with vital ecosystem services.

The FAO Regional Office for Asia and the Pacific in collaboration with regional governments and development partners has been working to strengthen efforts to balance the many potential trade-offs associated with bioenergy production. This publication is a compilation of papers presented at the FAO Sustainable Bioenergy Symposium on 'Improving resilience to high food prices and climate change', which was held in Bangkok in June 2011. It highlights a number of important policy issues associated with bioenergy developments in the region as well as practical approaches to address potential trade-offs. In doing so it offers valuable insights on how to ensure that bioenergy development in Asia enhances food security and benefits rural development and the environment and contributes to reduced GHG emissions.



Hiroyuki Konuma  
FAO Assistant Director-General and  
Regional Representative for Asia and the Pacific



# ACKNOWLEDGEMENTS

The volume is one output of the FAO Sustainable Bioenergy Symposium on 'Improving resilience to high food prices and climate change', which was held in Bangkok in June 2011 to coincide with Renewable Energy Asia 2011. The editors would like to thank the staff from the Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi and UBM Asia for their close collaboration in organizing this event.

Very special thanks goes to Robyn Leslie and Matthew Leete for their efforts in editing the final text, to Sansiri Visarutwongse for designing the cover and to Atchariya Mata for designing and formatting the full volume.

Finally, the editors would like to thank the authors of each paper for their support in bringing this volume to print. This volume is truly a shared effort.



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# EXECUTIVE SUMMARY

## SUSTAINABLE BIOENERGY IN ASIA

Patterns in the use of bioenergy have been a key indicator of changing fortunes in Asia and the Pacific. Formerly the key source of energy for the region's largely agrarian societies, rapid economic development over the past 50 years has resulted in a significant decline in bioenergy's share of total primary energy and replacement with fossil energy. This transition has opened up even further opportunities for development and change.

Despite the overall trend toward fossil energy in the region, high fossil energy prices and a growing need for more environmentally sustainable energy sources have encouraged many governments in the region to adopt policies to support the development of modern bioenergy sectors. This support for bioenergy has often taken the form of volumetric targets or mandates for a range of bioenergy sources complemented by policies designed to facilitate and support their achievement. These policies are often nationally focused and predicated on an assumption that plentiful and affordable biomass feedstock will be readily available from either existing agricultural production systems and agro-industrial wastes or modest expansion of bioenergy feedstock production.

The effect of these policies could be substantial. According to the International Energy Agency, over the next 20 years power generation from biomass and wastes in non-OECD Asia is projected to grow at 12.3 percent per annum, while biofuels consumption in the transport sector is projected to grow at 13.8 percent per annum. At minimum, this will result in a tenfold

increase in regional bioenergy and biofuel output by 2030.

The recent resurgence of agricultural commodity prices in the region has given renewed cause to question whether a sustainable expansion of biomass feedstock to satisfy both the regional energy needs of growing economies and food requirements of growing populations is, in fact, possible. If regional plans for bioenergy development result in increased competition for the natural resources that underpin already strained food and bioenergy feedstock production and distribution systems, regional food security could be affected.

## REDUCING COMPETITION BETWEEN FOOD AND FEEDSTOCK PRODUCTION

Bioenergy production systems require biomass feedstock that makes use of natural resources and other food system assets that could otherwise be used in food production. The possibility that bioenergy production has increased competition for these resources during times of continuing, widespread hunger is a common flashpoint for critics questioning the sustainability of bioenergy as an alternative energy source.

However, there are a range of existing bioenergy operations that have demonstrated that potentially dangerous competition between food and bioenergy production can be minimized or even eliminated. In many rural communities around the region, consortiums comprising community groups, government agencies and development organizations are also developing small-scale bioenergy systems to support their energy and food

requirements. In some cases the private sector has seized opportunities to create more efficient and profitable bioenergy systems employing waste utilization and flexible supply chain management to optimize production of both food and energy.

Greater effort is required to highlight these exemplary bioenergy systems and identify ways to further promote them through national and regional policy and financing frameworks for renewable energy and food security.

### **POLICIES AND FINANCING ARRANGEMENTS FOR RURAL BIOENERGY**

Despite Asia's rapid modernization, a substantial portion of the region's population lives without access to basic, reliable energy services. These people are usually located in rural and remote areas far from bustling industrial and urban centers. There are a range of bioenergy systems that could improve energy access for these communities and provide additional health and livelihood benefits. Unfortunately, due to the generally small scale of these bioenergy projects and need for sustained long-term technical support, there is often limited policy and financial support available to facilitate their establishment and operation.

Community and small-scale rural bioenergy projects usually do not adopt conventional business models nor meet donor timelines for program delivery. Efforts to build on success stories, standardize bioenergy technology and deployment practices and provide rural communities with access to finance for bioenergy projects are required to realize the potential benefits bioenergy could hold for remote and rural communities around the region.

### **CLIMATE-FRIENDLY BIOENERGY**

The region's capacity to produce increased biomass resources to satisfy the region's food and fuel industries will be further complicated by the anticipated impacts of climate change. Already the region has been subject to rising temperatures, declining rainfall and increased incidence of extreme weather events. These phenomena threaten the natural resources and ecosystem services that underpin the region's biomass production capacity.

As a renewable energy source produced from a range of waste and purpose grown biomass feedstock, bioenergy is often thought of in terms of the climate and its potential for offsetting greenhouse gas emissions. But this potential has been increasingly questioned; particularly due to concerns regarding direct and indirect land use change associated with the production of some biomass feedstock. This scrutiny is warranted.

Bioenergy production systems encompass a wide range of potential feedstock, conversion processes and by-product outputs. Each system has a different environmental footprint and potential impact on the drivers of climate change. Integrated bioenergy systems that utilize by-products such as bioslurry and biochar to rejuvenate and strengthen the natural resources underpinning biomass production are increasingly recognized not only for their potential to generate energy, but also provide other ecosystem services and act as important climate change adaptation measures.

More effort is required to highlight the multiple benefits of climate friendly bioenergy technologies and identify ways to strengthen their reach and appeal through carbon financing and environmental standards.







# *SECTION I: SUSTAINABLE BIOENERGY IN ASIA*

**BIOENERGY DEVELOPMENTS AND FOOD SECURITY IN ASIA AND THE PACIFIC**  
**BEAU DAMEN**

**BIO- AND RENEWABLE ENERGY FOR RURAL DEVELOPMENT AND POVERTY  
ALLEVIATION IN THE GREATER MEKONG SUBREGION**  
**MAURICE SCHILL AND SVERRE TVINNEREIM**

**SMALL-SCALE BIOENERGY SYSTEMS: FINDING A LOCAL WAY TO GENERATE  
ENERGY, STRENGTHEN COMMUNITIES AND BENEFIT THE ENVIRONMENT**  
**BASTIAAN TEUNE**

# Bioenergy developments and food security in asia and the pacific

Beau Damen<sup>1</sup>

## Introduction

Rapid economic development in Asia and the Pacific is resulting in a shift away from traditional, rural bioenergy towards fossil energy. However, higher fossil energy prices and a growing need for more environmentally sustainable energy sources have encouraged many governments in the region to adopt policies to support the development of modern bioenergy sectors. These policy choices can involve trade-offs, such as the potential for bioenergy to compete for the same natural resources that are used in food production, and therefore impact food prices and food security.

This paper assesses the role that bioenergy policy can play in determining the impact of bioenergy developments on food security. It will aim to demonstrate that the impact of bioenergy technologies on food security differs according to the feedstock, production system and set of supporting policies employed. This assessment will be used to identify strategies to assist policy-makers in designing more sustainable bioenergy development policies that avoid trade-offs with food security and also contribute to national and regional development goals.



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## Bioenergy overview

Bioenergy refers to the conversion of renewable biomass for energy. Generally, bioenergy can be further classified as either low-efficiency traditional bioenergy or high-efficiency modern bioenergy.

Low-efficiency traditional bioenergy refers to the combustion of fuelwood, charcoal, forestry residues and manure, often in poorer communities, for cooking and heating purposes. The average energy conversion efficiency of traditional bioenergy is between 10 and 20 percent (IPCC 2011). High-efficiency modern bioenergy refers to conversion of woody and agricultural biomass for stationary heat and power generation and the production of transport fuels. The average energy conversion efficiency of modern bioenergy is 58 percent (IPCC 2011).

Traditional and modern forms of bioenergy account for around 10.2 percent (50.3 exajoules) of global total primary energy supply (TPES)<sup>2</sup>. Traditional bioenergy sources account for the vast majority of this share. Agricultural biomass feeds 10 percent of global bioenergy output, 30 percent of which is derived from dedicated energy crops and the rest comes from residues and by-products (IEA 2009a).

1 Bioenergy and Climate Change Officer, FAO-Regional Office for Asia and the Pacific.

2 TPES is equal to gross indigenous energy production plus energy imports minus energy exports and reserves held in international marine bunkers; and adjustment for changes in energy stocks.

# Bioenergy policies in Asia and the Pacific

## Bioenergy supply and consumption

Bioenergy currently accounts for roughly 15 percent of regional TPES in Asia and the Pacific (Figure 1).

On a national basis, the share of bioenergy supply varies according to the level of economic development, national policy settings and industrial composition and configuration (Table 1).

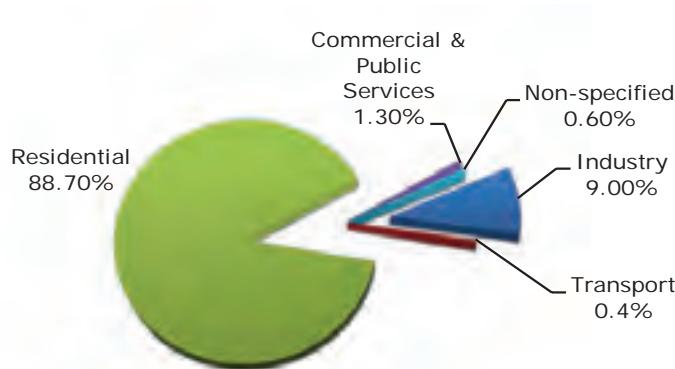
At the regional level, consumption of bioenergy is dominated by the residential sector, reflecting the high proportion of people in the region who still rely on traditional bioenergy for basic energy services such as cooking and heating (Figure 2).

Figure 1. TPES in Asia and the Pacific by energy source, 2008



Source: International Energy Agency (IEAb)

Figure 2. Final bioenergy consumption in Asia and the Pacific by sector, 2008



Source: IEAb

Table 1. TPES and bioenergy share in selected countries in Asia and the Pacific, 2008

Country	TPES (Mtoe)	Biomass/waste energy share of TPES (%)
Australia	130 113	4.2
Bangladesh	27 944	31.1
Cambodia	5 220	69.6
China	2 130 565	9.5
India	620 973	26.3
Indonesia	198 679	26.8
Japan	495 838	1.4
Malaysia	72 748	4.3
Myanmar	15 669	66.8
Nepal	9 799	86.4
New Zealand	16 935	6.1
Pakistan	82 839	34.8
Philippines	41 067	18.5
Sri Lanka	8 935	52.8
Thailand	107 199	18.6
Viet Nam	59 415	41.8

Source: IEAb

On aggregate, strong economic growth in the region and increasing consumer purchasing power has led to equally strong growth in the consumption of fossil energy sources such as oil, coal and gas. Over the medium term, this trend is expected to continue to meet the demands of the region's quickly developing economies.

However, population growth and persistent poverty, particularly in South Asia, will necessitate the continued use of traditional bioenergy to meet the basic energy needs of many consumers. Mirroring trends around the world, the consumption of modern bioenergy is also anticipated to grow at a rapid pace with the support of favourable government policies.

### The importance of policy in driving future bioenergy demand

Unlike fossil energy, bioenergy still faces substantial non-economic barriers such as poor infrastructure to reach markets and regulatory and administrative hurdles. Perhaps the largest barrier to bioenergy development in Asia and the Pacific is significant government spending on subsidies designed to

regulate the cost of fossil fuels for consumers. In 2008, Indonesia and Malaysia spent US\$22 billion and US\$14 billion respectively on fossil fuel subsidies (IEA 2009a).

Government support for bioenergy aims to address this issue by improving the competitiveness and profitability of the bioenergy sector. Many countries in the region have already implemented ambitious targets and/or mandates to promote renewable energy sources, including modern bioenergy and biofuels (Table 2).

To complement these commitments, governments have also adopted or are considering a range of supplementary policies including price support for feedstock production, feed-in tariffs, tax advantages, capital grants and/or loans and funding for research and development.

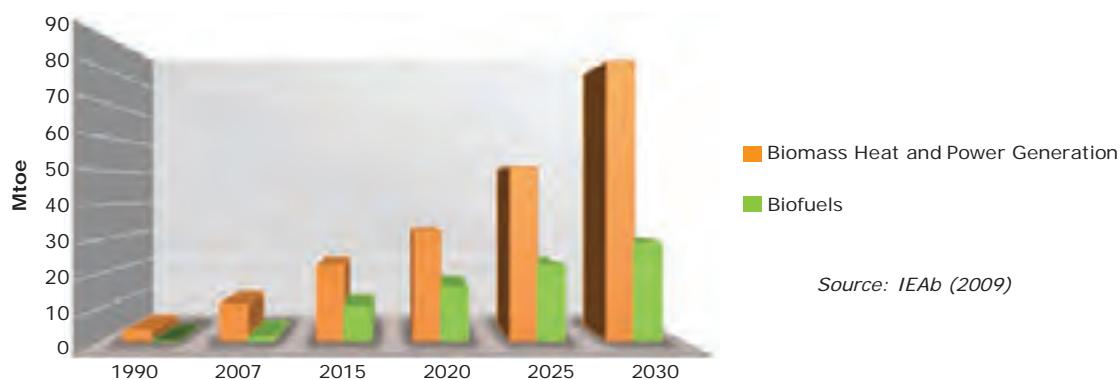
The effect of these policies could be substantial. According to the IEA, over the next 20 years power generation from biomass and wastes in non-OECD Asia is projected to grow at 12.3 percent *per annum*, while biofuel consumption in the transport sector

**Table 2. Bioenergy mandates and targets in selected countries in Asia and the Pacific**

Country	Biofuel mandates/targets	Biomass heat & power targets
China	E10 in nine provinces; 15 billion litres of biofuel consumption by 2020	30 GW by 2020
India	B10 & E10; B20 & E20 by 2017	1 700 MW of additional biomass cogeneration capacity by 2012
Indonesia	5% biofuel consumption in transport sector by 2025	810 MW by 2025
Malaysia	B5	1 065 MW by 2020
Philippines	B10 & E10; 1 885 million litres of biodiesel by 2030	267 MW by 2030
Thailand	B3 & E10; 5 billion litres of biofuel production by 2022	3 700 MW by 2022
Viet Nam	550 million litres of biofuel production by 2020	5% (30 GW) renewable energy by 2020 including biomass

Source: Renewable Energy Policy Network for the 21st Century (REN21)

**Figure 3. Actual and projected bioenergy output in Asia and the Pacific, 1990-2030**



is projected to grow at 13.8 percent *per annum* (Figure 3) (IEA 2009b). At minimum, this will result in a tenfold increase in regional bioenergy and biofuel output by 2030.

## Key objectives underlying bioenergy support policies

### Enhancing national energy security

The key objective underlying most of the bioenergy policies being adopted in the Asia-Pacific region is to enhance national energy security and reduce dependence on foreign fossil energy sources. Some countries in the region are already heavily dependent on imported energy sources (Table 3), and regional dependence on imported energy, particularly crude oil, is projected to increase over the next 20 years.

By 2030, net imports of oil to China and India are projected to account for 74 and 92 percent respectively of total national demand (IEAb 2009). In the Association of Southeast Asian Nations (ASEAN), dependence on imported oil is projected to grow dramatically from less than 30 percent in 2008 to over 70 percent in 2030. Over this period, annual expenditures on oil imports by ASEAN member countries are projected to grow from US\$32 billion to US\$164 billion (IEAb 2009).

Bioenergy is attractive for policy-makers because it is often a domestic source of energy that can

diversify national energy supplies and partially reduce energy import bills. For example, the United States Department of Agriculture (USDA) has estimated that China saved about US\$1 billion in oil imports in 2009 by using domestically-produced fuel ethanol (USDA 2010). Unsurprisingly, the increasingly oil import-dependent and biomass-rich countries of ASEAN have been some of the quickest in the region to adopt bioenergy support policies in the hope of realizing similar benefits.

### Reducing emissions and tackling climate change

Another common objective of national bioenergy policies is to reduce emissions from the energy sector as a means to tackle climate change. On a regional basis, Asia and the Pacific is the largest emitter of greenhouse gases in the world. Since 1960, CO<sub>2</sub> emissions per capita have grown by an average rate of 3.2 percent *per annum*. Total regional emissions of CO<sub>2</sub> are projected to increase by almost 80 percent between 2007 and 2030 (IEAb 2009).

The latest evidence confirms that some bioenergy production chains emit less greenhouse gas emissions than their fossil energy counterparts (IPCC 2011). Generally, using bioenergy in heat and power generation is a more cost- and land-efficient way to reduce greenhouse gas emissions than producing biofuels for the transport sector, particularly if coal is the fuel replaced (IEAa 2009).

**Table 3. Net energy imports of selected countries in Asia and the Pacific, 2008**

Country	Net energy imports (Mtoe)	Net energy imports as a share of TPES (%)
Australia	-167 021	-128.4
Bangladesh	4 930	17.6
Cambodia	1 612	30.9
China	210 425	9.9
India	418 891	84.5
Indonesia	157 888	25.4
Japan	-147 335	-74.2
Malaysia	-17 608	-24.2
Myanmar	-7 292	-46.5
Nepal	1 138	11.6
New Zealand	2 930	17.3
Pakistan	20 214	24.4
Philippines	18 804	45.8
Sri Lanka	4 237	47.4
Thailand	46 235	43.1
Viet Nam	-10 629	-17.9

Source: IEAb

Note: Exports are considered to have a negative value when calculating net energy imports.

Capturing emissions benefits from bioenergy systems is highly dependent on feedstock and avoiding direct and indirect land-use changes. For example, research conducted by FAO in Thailand has demonstrated that ethanol produced with cassava that required land-use change away from pastureland or crop change away from sugar cane or rice results in greater greenhouse gas emissions per unit of fuel than fossil gasoline (FAO 2010a).

### **Fostering rural employment and development**

Governments have also supported bioenergy because of a widely-held belief that modern bioenergy systems create employment and development in rural areas. Recent studies indicate that bioenergy has a larger positive impact on job creation in rural areas than other energy sources (IPCC 2011). However, whether the jobs created represent a net gain for rural employment depends on the type of bioenergy system.

In the case of bioenergy derived from purpose-grown biomass, the employment benefits that result from the bioenergy system depend on the relative labour intensity of the feedstock crop that was previously grown on the same land (FAO 2008a). For example, if the bioenergy feedstock is less labour-intensive than the previous crop or land-use regime, the bioenergy system will result in a net reduction in employment at the farm level.

Successful small-scale, community-based bioenergy systems in Asia – such as biogas digesters, improved cook stoves and microscale biofuel production – have demonstrated that the construction, marketing and maintenance of small-scale bioenergy systems, sometimes with government support, can also create jobs in rural communities.

In rural areas with limited or no access to electricity, small-scale bioenergy can generate additional benefits for rural development. Improved access to clean and efficient bioenergy reduces opportunity costs associated with feedstock collection and respiratory health problems associated with traditional bioenergy cooking. Poor access to electricity is still a major issue in Asia and the Pacific: in 2008, over 800 million people in Asia lacked access to electricity. This number is projected to decline by 2030, but the number of people without access to electricity in the region is still projected to remain above 500 million (IEA 2009).

### **Bioenergy and food security**

Because government resources are limited, policy choices such as those outlined above involve trade-offs. Government action to promote bioenergy may limit other strategies to achieve similar development objectives. Also, because of information gaps, bioenergy policies designed to achieve one set of development objectives can result in unintended consequences. Perhaps the clearest and most serious example of the trade-offs associated with bioenergy development is its potential to influence food prices and food security.

### **Bioenergy's impact on food security**

According to FAO's Bioenergy and Food Security (BEFS) Analytical Framework, bioenergy affects food security primarily through two channels. First, bioenergy competes for resources used in food production such as land, water and labour (FAO 2011). Competition between the food and bioenergy sectors for these resources will invariably increase the cost of food production and food prices, at least in the short term.

For example, biofuels produced from agricultural crops have been identified as one of a number of factors driving up global food prices over the past decade. While the overall use of agricultural crops for biofuel production on the global level is relatively small, the sector's current focus on a small number of key feedstocks (e.g. maize and palm oil) has raised the possibility that world market prices of these products will be higher than if biofuels were not produced (FAO *et al.* 2011). Eventually this situation can also affect product substitutes not used as biofuel feedstock (e.g. wheat) as they may be substituted to satisfy demand in consumption or replaced as a result of the competition for land and other inputs (FAO 2011).

Growing financial trade in energy and agricultural commodities and, to some extent, increased biofuel output have also created a situation in which agricultural prices at the global level are increasingly influenced by movements in energy prices (World Bank 2010). This growing bond between global food and energy markets is expected to lead to global food prices remaining higher over the short to medium term than they were in the decade before 2007.

In general, higher food prices will pose an immediate threat to the livelihoods and food security of poor net food buyers who spend a very large share of household expenditures on food. Higher food prices will also drive more households into poverty, creating



further negative implications for food security. The Asian Development Bank (ADB) has recently estimated that a 10 percent rise in domestic food prices in developing Asia could push an additional 64.4 million people into poverty (ADB 2011).

The second channel by which bioenergy interventions can impact food security is through changes in agricultural productivity, biomass utilization and other factors that influence food security, such as economic growth and employment (FAO *et al.* 2011). For example, if higher food and agricultural prices motivate governments, the private sector and donors to increase investment in agriculture and biomass collection and distribution networks, there is potential for bioenergy development to result in gains for agricultural output and food security. Investment that increases agricultural output per unit of input and encourages the sustainable utilization of food system resources could benefit rural communities and food security (FAO *et al.* 2010a). These impacts generally manifest themselves over a longer time horizon.

### Regional dimensions of bioenergy and food security

In regions such as Asia and the Pacific, where some countries have committed to significant growth in bioenergy output, it is also important to consider the potential implications of these policies for food security at the regional level.

Differences in national natural resource endowments and biomass production capacity may require that some countries trade biomass feedstock or bioenergy to support their national policy commitments. For example, the magnitude of China's expected future demand for ethanol and restrictions on biofuel produced from grain have prompted plans for a series of cassava-based feedstock and biofuel production operations in the Mekong region.

Trade in bioenergy and feedstock implies the use of a country's land and water resources to produce fuel and energy for another country. While trading natural resources between countries in the form of food crops can have significant benefits for regional food security,

particularly in low-income food-deficit countries, the implications of increasing trade in these resources to meet growing regional energy demands is not as clear. If not properly managed, a future scenario where bioenergy replaces larger and larger shares of fossil energy could intensify regional competition to secure renewable biomass feedstock. There is also a risk that bioenergy feedstock producers in one country looking to take advantage of favourable bioenergy policies in another may engage in unsustainable practices that will affect the quality and stock of a country's natural resources, leading to longer term issues for local food security.

### The impacts of different systems

Finally, when considering bioenergy's impact on food security, it is important to remember that some bioenergy systems more or less imply competition for resources used in food production. As a result, the final impact of bioenergy on food security will, to some extent, depend on the types of bioenergy systems that are adopted.

As noted above, bioenergy produced from agricultural commodities and residues such as biofuels have the strongest links to agricultural markets and the greatest potential to impact food production and prices. Bioenergy produced from purpose-grown forest plantations and second-generation bioenergy derived from lignocellulosic biomass may have fewer direct links to food production systems, but could still compete for land and water resources in feedstock production.

In contrast, bioenergy produced from forestry residues and municipal and industrial wastes will result in little competition for agricultural resources. Similarly, small-scale bioenergy systems have no discernible impact on local food security (FAO 2009). Some small-scale bioenergy systems aim to create additional benefits for local food and energy security by integrating food and energy production. These integrated food and energy systems (IFES) facilitate the simultaneous production of food and energy through sustainable crop intensification and improved resource efficiency (FAO 2010b).

## Strategies to avoid trade-offs between bioenergy and food security

As outlined above, the impact of bioenergy on food security may be positive or negative, depending on conditions prevailing at the local, national and regional levels and on the chosen feedstock production system and technology pathways. As a result, policy-makers' choices regarding the structure and composition of bioenergy sector policies will influence national and possibly regional food security.

The following strategies should be considered to avoid potential trade-offs between bioenergy development and food security.

### ***Ensure policies are based on a detailed assessment of the trade-offs involved:***

Bioenergy can only represent a sustainable alternative energy source if natural resources are managed responsibly; biomass yields from the agriculture and forestry sectors increase substantially; and risks to food security are moderate. To meet these challenges, bioenergy development policies being considered or adopted should be based on a solid understanding of the potential trade-offs involved.

Assessing these trade-offs will require access to a range of data and information that shows the many varied consequences of bioenergy development on food security, poverty reduction and rural development in specific country contexts. For example, with BEFS, FAO is able to produce a range of data, information and analysis using a number of established tools and methodologies such as the FAO commodities simulation forecasting model (COSIMO), land suitability assessment, virtual water footprint analysis, life cycle assessment and computable general equilibrium modelling.

Access to this type of information will strengthen government capacity to assess the impact of planned bioenergy developments and better manage the potential trade-offs involved.

**Protect the poor and vulnerable against food insecurity:** As noted above, the world is entering a new era of higher food prices, and some bioenergy developments, supported by government policies, are contributing to this trend. Food security should be the ultimate priority of country governments in the region. This priority needs to be reflected in national bioenergy policies – either through measures to limit competition for food system resources or to mitigate the potential for higher prices to worsen the food security situation of poor and vulnerable groups.

At a minimum, policies to support bioenergy development should be accompanied by efforts to identify groups of poor and vulnerable people and design appropriate safety nets to preserve and/or improve their food security position. Specific measures could include direct food distribution, targeted food subsidies and cash transfers and nutritional programmes such as school feeding (FAO 2008b).

In some cases, such as when biofuel production results in direct competition with food system resources, more drastic action should be considered. In a recent submission to the G20 on price volatility in food and agriculture markets, a group of multilateral agencies, including FAO, suggested that removing provisions which artificially stimulate demand for biofuels is the best way to avoid policy-driven conflict between food, feed and fuel (FAO *et al.* 2011). However, devising measures that will allow the flexibility to suspend bioenergy subsidies or mandates necessitate complicated policy levers that could present significant design challenges for governments.

### ***Avoid harmful environmental impacts:***

Bioenergy systems that avoid harmful environmental impacts and encourage efficient resource utilization will ensure the long-term productive capacity of a country's stock of natural resources for both food and energy production.

The environmental impact of bioenergy systems is highly dependent on whether land-use or crop changes are involved in the biomass feedstock production process and the extent to which the system affects the volume and quality of local water resources. In particular, high-risk areas, such as those rich in biodiversity or at risk from water scarcity, need to be identified and protected from bioenergy developments.



Measures to improve natural resource governance techniques, such as agro-ecological zoning, are suitable strategies to maximize the productivity of natural resources and avoid negative environmental impacts (IPCC 2011). However, many governments in the region do not yet have the technical capacity to adopt such data-intensive planning tools. FAO has been working with country governments through initiatives such as BEFS to design tailored resource planning solutions that accommodate these capacity limitations.

#### ***Invest in lifting agricultural productivity:***

Any bioenergy policy framework that aims to avoid trade-offs with food security depends on raising agricultural productivity to meet demand from the food and energy sector. Realizing productivity growth in the agriculture sector will necessitate investment in long-neglected areas such as research, extension, agricultural and general infrastructure along with credit and risk management instruments (FAO 2008b). Investment to improve the yields of bioenergy feedstock production per unit of natural resources will also have the added benefit of reducing pressures to expand the area designated for bioenergy feedstock production and the risk of harmful land-use changes.

#### ***Ensure smallholders and rural communities will benefit:***

Smallholder farms still account for a significant proportion of agricultural output in Asia and the Pacific. Measures to better integrate smallholder farmers into national bioenergy policies and production chains can work to strengthen their resilience to higher food and energy prices. To facilitate their involvement in bioenergy production chains, governments, and to some extent donors, need to enhance smallholders' access to extension and financial services and ensure their access to natural resources (FAO 2008b).

Small-scale bioenergy systems should be encouraged as a supplementary investment in the food security, health and productive capacity of rural communities. Successful deployment of small-scale bioenergy technologies requires investment in technology selection, local technical capacity and maintenance and support networks. A number of governments in Asia have already made these types of investments

in small-scale bioenergy systems with positive, observable benefits for rural communities, such as the national biogas programmes in Cambodia, the

Lao People's Democratic Republic (Lao PDR), Nepal and Viet Nam.

#### ***Encourage integrated food and energy systems (IFES):***

IFES offer an innovative, resource-efficient strategy to address food security and rural development. IFES can operate at different scales and configurations involving either the production of food and bioenergy feedstock crops on the same land using multiple-cropping or agroforestry systems; or the adoption of agro-industrial technologies, such as biogas digesters, that allow for the maximum use of all wastes and by-products (FAO 2010b).

FAO has identified and documented a range of successful IFES projects in Asia and the Pacific (FAO 2010c). Learning from these experiences, raising awareness of their potential benefits and leveraging increased national and donor support will be essential in realizing the significant potential of this innovative approach to enhance local food and energy security and rural development.

#### ***Prepare to adopt second-generation bioenergy technologies:***

Second-generation bioenergy produced from lignocellulosic biomass and photosynthetic organisms such as algae could lessen competition for land with food and feed production and provide even greater greenhouse gas emission benefits than existing bioenergy technologies. However, significant technological and financial challenges still remain in bringing these energy sources to market. The most optimistic estimates anticipate that the commercial production of second-generation bioenergy will commence around 2020 (IPCC 2011).

Governments with significant modern bioenergy sectors should look to encourage investments in adapting existing infrastructure to accommodate second-generation bioenergy development. Some governments in the region, such as Australia, China, India and Thailand, have already incorporated support for research and development of these technologies into national bioenergy policies, including assistance to demonstrate these technologies in existing bioenergy production facilities.

However, limited financing possibilities and a lack of skilled labour and suitable infrastructure will restrict the ability of other countries in the region to adopt

such proactive strategies. Strengthening national bioenergy sectors will constitute the best strategy for governments looking to take advantage of second-generation bioenergy technologies. The presence of existing facilities and infrastructure will allow for the fast adoption of these technologies as they become available.

### ***Develop regionally-agreed criteria and standards:***

Regionally-agreed sustainability criteria and standards for biomass feedstock and bioenergy production should be considered as a means to encourage more sustainable and efficient use of natural resources and biomass to produce energy. Establishing regionally-agreed standards and monitoring mechanisms also will work to mitigate the risk that poorly-coordinated national bioenergy commitments will lead to unsustainable competition for biomass resources with downside risks for regional food security.

There are a number of recent developments that governments in the region could build on to develop regionally-agreed standards for bioenergy. Under the direction of ASEAN energy ministers, the Economic Research Institute of ASEAN and East Asia (ERIA) has undertaken a sustainability assessment of biomass utilization based on a set of environmental, economic and social criteria. Also, in May 2011, 45 countries and 22 international organizations under the Global Bioenergy Partnership (GBEP) reached agreement on 24 indicators for practical, science-based, voluntary sustainability indicators for bioenergy. These indicators cover issues such as food prices, water quality, greenhouse gas emissions and energy access, and they offer an invaluable guide for policy-makers to enhance the environmental and social sustainability of the bioenergy sector.

## **Conclusions**

Modern bioenergy development in Asia and the Pacific is expected to grow substantially in the near to medium term with the support of government policies. These policies have been enacted to achieve a range of national development objectives, including energy security, improved environmental performance and rural employment and development.

Because of competition for natural resources and biomass feedstock, certain bioenergy systems can impact food prices and food security, particularly in poorer communities. Bioenergy policies could also create competition for food system resources at the regional level.

To avoid trade-offs between bioenergy and food security, a range of strategies should be considered. The most important element is a comprehensive assessment of the bioenergy sector and the natural resources that underpin food and bioenergy feedstock production systems. This assessment should be used to trigger strategies that will safeguard the food security of the poor and vulnerable, avoid harmful environmental impacts, realize complementary opportunities for agricultural investment and smallholder inclusion and investigate pathways to adopt second-generation bioenergy and regionally-agreed bioenergy indicators.

Through BEFS, FAO has already developed the tools necessary to assist member countries conduct national-level bioenergy assessments and identify suitable strategies to ensure sustainable bioenergy development at national and regional levels.



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# Bio- and renewable energy for rural development and poverty alleviation in the Greater Mekong Subregion

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## Introduction

Between 2009 and 2010, the FAO Regional Office for Asia and the Pacific and several local capacity builders partnered to explore opportunities for renewable energy development in rural areas of the Greater Mekong Subregion (GMS), in particular in Cambodia, Lao PDR, Myanmar and Viet Nam. In collaboration with national ministries, FAO was instrumental in:

1. Establishing a Renewable-Energy Activity Database (READ) to provide an overview of renewable energy programmes and projects in the GMS.
2. Producing 16 case studies that document existing experiences with renewable energy in the GMS to highlight best practices and challenges for development of the sector.
3. Organizing practitioners' meetings in Phnom Penh, Vientiane, Hanoi and Yangon with representatives from governments, the private sector, banks, small-scale bioenergy providers and development organizations to share experiences and consider practical solutions to enhance renewable energy development in the GMS for the benefit of rural communities..



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This report describes the findings of these activities and possible avenues for action to better integrate small-scale, community-based renewable energy solutions into future energy and poverty reduction policies in the GMS. More detailed information, including the preliminary READ, complete individual case studies, contacts and a summary of the proceedings from the practitioners' meetings is included on the CD-ROM attached to individual booklets for each country.

## General overview

Between 60 and 70 percent of the GMS's population live in rural areas with most people relying on traditional fuelwood for lighting, cooking and heating. Access to efficient and clean energy services is increasingly being recognized as essential for broad-based socio-economic development. While the GMS governments plan to provide nationwide electricity access in the near to medium term, it is anticipated that a significant proportion of the rural population will continue to rely on traditional biomass energy for basic energy services. Delivering energy services on a large scale, in a way that will benefit most GMS people living in rural areas, represents a formidable challenge.



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Ministries of agriculture, energy, industry and/or electricity in the subregion have initiated policy frameworks for renewable energy development utilizing a range of biogas, biomass, biofuel, solar and microhydro technologies, among others. FAO and local capacity builders are partnering with these ministries to examine the potential of such technologies for rural development and income generation in the GMS.

## Renewable Energy Activity Database (READ)

GMS countries possess agricultural resource bases and appropriate climatic conditions to support a wide range of renewable energy technologies. The different agroclimatic zones including the extensive delta region, long coastal strips, Mekong Basin, and the hilly regions facilitate the use of biofuel, biogas, biomass, microhydro and solar technologies.

READ was established to monitor the renewable and bioenergy situation in the GMS. It identifies key players and programmes in both the private and public sectors. If maintained, READ could present a very useful tool for decision-makers and donors looking to identify needs, avoid duplication and create complementarities in programme implementation. According to the database, there are currently 182 renewable and bioenergy projects and programmes underway or under development in the four countries, worth a total of US\$703 million (Table 1).

**Table 1. READ status at the end of 2010**

Country	Investment (US\$ million)	Number of projects
Cambodia	41.8	34
Lao PDR	290	73
Myanmar	370	55
Viet Nam	1.6	20
Total	703.4	182

Source: READ GMS-FAO

**Table 2. List of case studies in selected countries**

Country	Case studies
Cambodia	National Biogas Program: Credit facilities for biodigester
	Biofuel: A community based approach
	Wind-water pumping
Lao PDR	Developing household biogas in Lao PDR with access to CDM
	Solar recharging stations: Selling hours of solar lighting
	Biomass gasification
	Improving the utilization of pico hydropower in Lao PDR
	Recycling of agricultural residues for biomass energy production
Myanmar	The low cost biodigester
	The Renewable Energy Revolving Fund
	Rural electrification with micro-hydro power
	Biogas plants for rural livelihood
Viet Nam	Biogas program from SNV
	VACVINA biodigester
	New rice husk gasification technology
	Biofuel smallholders and green energy

Source: READ GMS-FAO

## Renewable energy case studies

Sixteen case studies were selected by FAO and local capacity builders to demonstrate the potential of small-scale technologies to contribute to rural development in the GMS. The selected cases also point to challenges and constraints that are common elsewhere in the region. The case studies indicate that there is a potential to expand the reach of renewable energy in the GMS. The cases identified abundant, untapped renewable energy feedstocks and examples of productive collaboration between researchers, investors and development organizations. However, the cases also demonstrated that there are still hurdles to expanding access to renewable energy for rural communities in the GMS. The most significant challenges are ensuring that technologies are appropriate for target communities and affordable for low-income households. Addressing these challenges will require more coordinated support from relevant government agencies, better access to information, stronger local capacity and access to innovative financing mechanisms. Fully developed case studies are available on the CD-ROM for each country. The selected cases are identified in Table 2:

### Cambodia – wind-water pumping

Rice farming is the main economic activity of farmers in rural Cambodia. On average rural families have 1.5 hectares of land for rice farming, from which they typically obtain revenue of only US\$750 per year. At present, only a very small percentage of farmers in Cambodia grows two seasons/crops per year, even though water sources are readily available. One of the main reasons for this is that only a few have pumping equipment and that the cost of the principal sources of energy available – diesel and electricity – are too high. In comparison to Viet Nam, the cost of electricity in rural areas in Cambodia is 3-4 times higher (US\$0.55-US\$1.00 per kilowatt hour).

In an attempt to address this problem, the Cambodian Development Institute (CDI) is promoting a version of wind-water pumping using 'rope pump' technology. This technology is already available in many other developing countries, serving thousands of people. Over the last five years, CDI has developed ten different models and has recently installed six demonstration model windmills along major roads on the outskirts of Phnom Penh. The project has

been able to generate interest from private investors and landowners and consequently 20 wind-water pumps have been sold so far and orders for at least 30 more have been secured by private farmers.

### Lao PDR – improving the utilization of pico hydropower

The pico hydropower case study examines the Lao Institute of Renewable Energy's experiences with implementing microhydro technology in rural communities in Lao PDR. The case study details some of the bottlenecks encountered in distributing the technology and interventions that were employed to improve the uptake, quality and safety of pico hydropower systems.

### Myanmar – the low cost biodigester

The lead institution for the elaboration of the Low Cost Biodigester (LCB) in Myanmar is Myanmar Agricultural Produce Trading under the Ministry of Commerce. The LCB is made from bamboo mats covered with liquid rubber. During the first two years of the programme, more than 50 villages were equipped with the LCB technology. For consumers the potential benefits are multiple and include: a) low cost technology – one unit costs 65 000 kyats (US\$65.00), b) ease of installation, c) improved health as a result of reduced smoke and soot from cooking and d) significant time savings through a reduced need for fuelwood collection and household cleaning

### Viet Nam – new rice husk gasification technology

This case details the work of Tan Mai Ceramic Co. Ltd. in developing a model for rice husk gasification that can be employed by communities in Dong Thap Province. This work is being supported by local governments, commercial banks, the private sector (equipment supplier, engineering service providers) and the United Nations Development Programme (UNDP) to provide a viable alternative energy source to coal. The environmental issues associated with the burning of coal in brick kilns in Dong Thap Province are considerable, which has prompted the provincial government to ban the practice. It is hoped that this new bioenergy technology will make productive use of waste rice husks, reduce local air pollution and, importantly, provide a sustainable energy source.



## Practitioners' meetings

Practitioners' meetings were held in Phnom Penh, Vientiane, Hanoi, and Yangon and each event involved approximately 35 participants from the public, private and development sectors. The main objective of the meetings was to develop practical solutions to enhance the delivery of efficient, reliable and clean bioenergy in the GMS for the benefit of rural communities – particularly the rural poor. The events also provided an opportunity for knowledge sharing and networking among key practitioners in the field in the GMS.

Several group discussions and working groups were organized during the meetings to allow for more focused discussions. First the participants were asked to identify the main opportunities and challenges associated with renewable energy (RE) development in the GMS. The main outcomes of these discussions are summarized below.

Opportunities	Challenges
Wide range of possible RE options including biomass, solar, agricultural waste, biofuel, microhydro and biogas	Poor access to finance and lack of investment
Providing clean energy for households	Lack of information regarding appropriate technologies
Provides an alternative source to meet GMS's growing energy needs	Knowledge sharing and information regarding bioenergy is weak
RE development is an appropriate way to utilize GMS's abundant renewable energy resources	Lack of clear policy
Presence of various donors in the GMS	No incentives for investment in the RE sector
	Certain technologies not appropriate to all locations and climates

*Source: Discussions at practitioners' meetings*

Having identified opportunities and challenges for the sector, participants formulated priority areas that need to be addressed to better integrate renewable energy and rural development concerns into existing policy frameworks in the GMS. Participants were asked to specify a goal for each priority area and develop sets of actions that could be employed to realize these goals. An overview of the results is given in Table 3.

**Table 3. Priority areas, goals and action for RE and rural development in the GMS**

Priority Areas	Goals	Action
Policy	Facilitate enabling environment for RE including the creation of public-private partnerships	Establish a high-level coordination body. Strengthen national and regional policy networking mechanisms. Investigate opportunities for public-private partnerships.
Technology	Improve different types of technologies appropriate for GMS agro-ecological conditions	1: Encourage collaboration with international technical organizations. 2: Pilot projects in remote areas that will demonstrate potential in terms of income generation.
Finance	Increase investment in RE threefold over the next three years	1: Elaborate practical guidelines to facilitate access to finance for Private Sector. 2: Strengthen capacities of service providers (NGOs, CSO, PS). 3: Initiate easily accessible funding for RE development.
Knowledge	Raise awareness of the benefits of RE and build capacity on RE	1: Follow up with donors regarding possibilities (ADB-WGA). 2: Establish national expert group and organize appropriate study tours.

*Source: Results of practitioners' meetings*

## Conclusion

During the implementation of the technical cooperation project Bioenergy for Rural Development and Poverty Alleviation in the Greater Mekong Subregion huge differences among the countries involved were found. Hence, what might be relevant issues and possible solutions in one location may not be of interest to other communities. Moreover, some technologies (in particular the use of carbonized wood briquettes) have a future predominantly as a niche product only in certain geographical 'pockets' and it would probably be futile to promote them for widespread use in the entire sub-region.

Despite discrepancies and different local circumstances one feature seems to be a common denominator in describing the choice and success of bioenergy initiatives: the involvement of local 'champions' who push for something to happen. In some cases it is one individual that advocates a certain technology, and in some cases it is an entire community that decides to try something different. But without this passion, bioenergy initiatives seldom emerge by themselves or they become a long-term, sustainable solution.

Stocktaking of the bioenergy sector in the region also revealed that bio- and renewable energy is still associated with much uncertainty; extension and knowledge-sharing services need to be strengthened. The technology applied often needs to be relatively simple to use, it has to be supported by an operational system of maintenance and there ought to be realistic avenues for the consumers to finance the renewable energy devices they decide to acquire. The latter also raises the issue of informing financial actors about the risks involved with bio-/renewable energy technologies, as it is our understanding that uncertainty drives up the interest rates they demand for their investments.

Bioenergy is at the heart of multiple policy areas, such as economic development, environmental concerns and energy security. Any single policy to address all policy objectives simultaneously is likely to be ineffective. Similarly, policies aimed at addressing only one policy objective (for example reduction in greenhouse emissions) might turn out to make the overall situation worse. A successful policy framework will hence require a multifaceted and coordinated response that accounts for policy trade-offs.

Creating an environment for informed and incremental processes is not straightforward and will require:

- Accurate knowledge of technological options and the local social, ecological and economic environment of the place where interventions are being planned.
- Setting of clear policy goals; cognizant of all policy trade-offs.
- Open channels of communication between relevant government entities, industry and community stakeholders.
- Willingness to shoulder costs, at least initially. At the same time it is important to have a conscious handling of subsidy policies as the long-term goal must be economic viability.
- Flexibility to adapt policies to new information and changing circumstances.



# Small-scale bioenergy systems: Finding a local way to generate energy, strengthen communities and benefit the environment

Bastiaan Teune<sup>1</sup>

## Introduction

Energy poverty prevails for half of the world's population and poses severe consequences for women's livelihoods especially. Exposure to smoke from traditional biomass burning for cooking and heating causes 2 million premature deaths annually. This situation can change dramatically through mass dissemination and capacity building programmes of appropriate household technologies, such as improved cook stoves and domestic biogas plants. Official Development Assistance (ODA), national governments and carbon financing mechanisms play a crucial role in financing these programmes to significantly tackle this major challenge



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## A vulnerable world by day

From space the earth looks different from how we know it; without the visible presence of humans, country borders, politics, religions and disparities in welfare. There is no evidence of the major global challenges we face today: poverty, energy crisis and climate change (Plate 1).

In the Oscar-winning documentary *An Inconvenient Truth* (2006), Al Gore says, "The picture below was taken on the last Apollo mission, Apollo 17. This one was taken on December 11, 1972 and it is the most commonly published photograph in all of history. And it is the only picture of Earth from space that we have where the sun was directly behind the spacecraft so that the Earth is fully lit up, and not partly in darkness." This image brought forward a public sense of concern and vulnerability of our planet and has stimulated environmental consciousness around the world ever since.

Plate 1. The world by day



Source: Google

<sup>1</sup> SNV Renewable Energy Sector Leader in Lao PDR



## Energy poverty illuminated by night

Source: Wikipedia

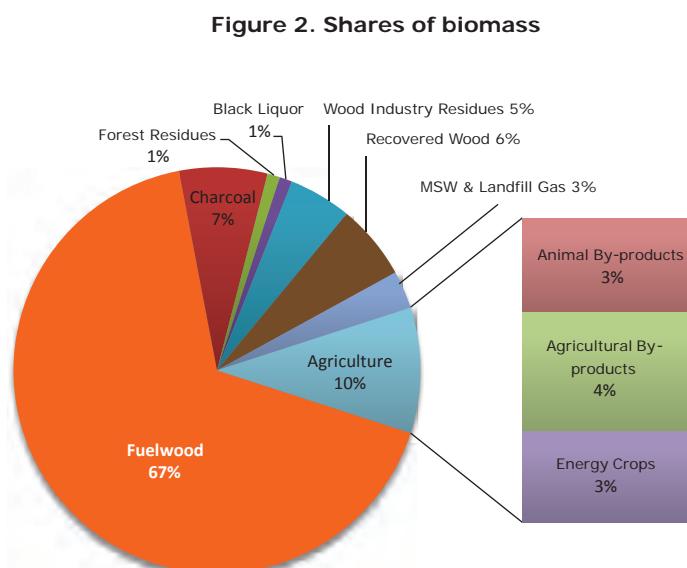
But when the sun is on the other side of the earth and night falls, immediately our ubiquitous presence is revealed by the illuminated zones on different continents (Plate 2).

However in the context of quality of life worldwide, the alarming conclusion is that one-third of its population does not have access to electric light. *Vis-à-vis* thermal energy, 2.7 billion people cook with traditional solid fuels instead of gas and electricity and live in darkness. Collection of traditional fuels and production of charcoal can exhaust natural resources and damage the environment. The urge for promoting renewable sources of energy is becoming crucial.

## Renewable energy and bioenergy

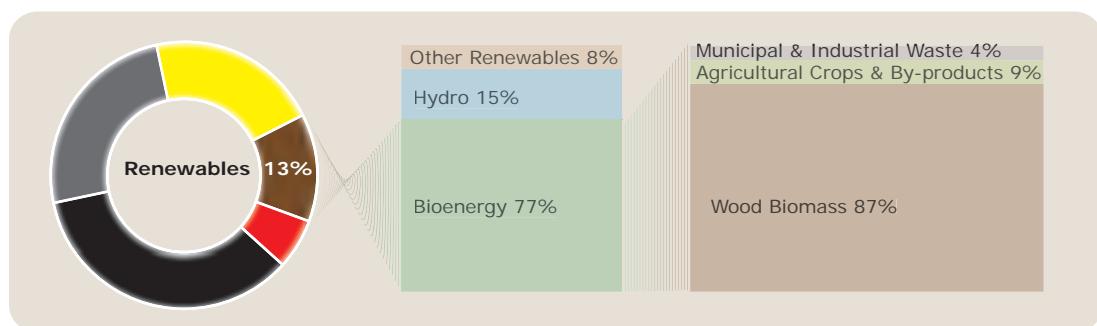
According to the World Energy Council (2010), only 13 percent of global energy consumption is regarded as renewable. Of the share of 'renewables', close to 77 percent is bioenergy, of which 87 percent is wood.

Biomass sources consist of 87 percent fuelwood and seven percent charcoal – the predominant energy sources for cooking in developing countries. Thus at least 50 percent of renewable energy sources worldwide derive from traditional energy cooking sources. Although it is debatable whether all of this biomass can be considered as renewable, it accounts for just 6 percent of global energy consumption.



Source: Based on data from the IPCC, 2007

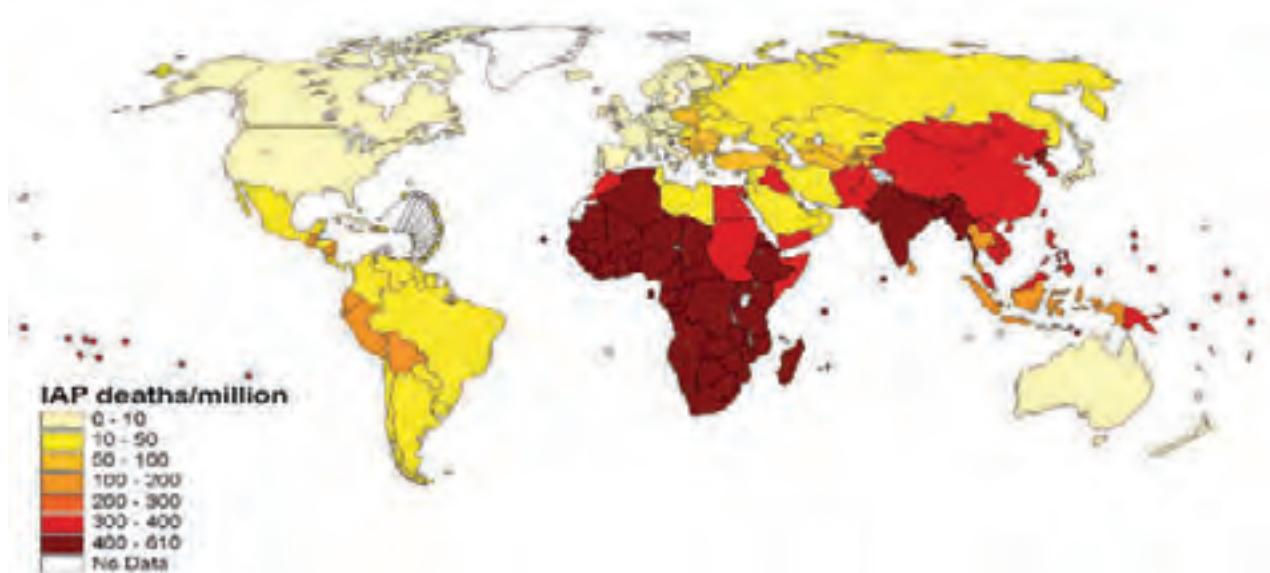
Figure 1. Primary energy sources in the world



## Smoke, the killer in the kitchen

There is a sinister side to the use of biomass fuels. Those who cook on traditional fuels such as wood, charcoal and dung suffer from smoke that pollutes the air in the kitchen and living areas. Women in particular are prey to respiratory diseases, causing the premature deaths of 2 million each year, surpassing the number of victims from malaria (Figure 3).

Figure 3. Mortality from indoor air pollution



Source: WHO 2005

Note: Estimates by WHO sub-region for 2000 (WHO Health Report 2003)

## Collecting fuel takes time

Energy-poor families need to collect wood daily for their cooking and heating needs. This takes considerable time and results in high opportunity costs to make a better living. According to an assessment made by Practical Action (2010), there are families in Nepal that need to allocate up to 40 hours per week to collect fuelwood.

Plate 3. Common cooking practices in developing countries (SNV 2011)



## Access to energy is conditional to development

The global community recognizes that lack of access to modern energy services has a negative impact on socio economic development. In 2000 the United Nations agreed on the Millennium Development Goals (MDGs) to halve poverty by 2015.

Universal energy access is a key priority on the global development agenda. It is a foundation for all the MDGs (United Nations Secretary-General, Ban Ki-moon, 2010)

One delegate at the 2010 Ashden Award ceremony in London put it this way, “Lack of access to modern energy is not the result of poverty; it’s the cause of it.”

## Global warming and the Clean Development Mechanism

Gore's *An Inconvenient Truth* revealed explicitly that global warming is taking place and that it jeopardizes the future life on earth, especially for humans. Global warming is now widely acknowledged to be the result of anthropogenic emissions; to mitigate these human-induced emissions, the Clean Development Mechanism (CDM) was put in place under the Kyoto Protocol in 1992.

The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each dominated by 1 ton of CO<sub>2</sub>. These CERs can be traded and sold, and used by industrialized countries to a meet part of their emission reduction targets under the Kyoto Protocol.

The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets (<http://cdm.unfccc.int> May 2011).

### The CDM does not reach the energy-poor

However, as Figure 4 shows, so far the mechanism bypasses all 'least development countries' (LDCs) with their small industries and few polluting activities. The greenhouse gas (GHG) emission mitigation potential in LDCs is for small-scale household technologies such as cook stoves, domestic biogas and pico hydropower, domestic water purification systems and solar home systems. These technologies reduce GHG emissions and enhance the livelihoods of those who are most vulnerable to the consequences of global warming.

Currently, however, 74 percent of the registered CDM projects occur in just four countries – China, India, Brazil and Mexico. These are countries on the brink of becoming developed nations. Only a marginal number of projects focus on household energy technologies such as improved cook stoves and domestic biogas; the majority supports the energy efficiency of large industries.

### Energy poverty insufficiently addressed

The CDM is not the only mechanism to neglect energy poverty; in many energy policies energy-poor households are often omitted. In the 618 pages of the *Survey of energy sources 2010*, the word cooking is mentioned only eight times. The 338 pages of the IEA's *International energy outlook 2010* fail to mention cooking and stoves can be found seven times only. Also national energy policy documents often fail to address household energy properly. For major investors and development banks, (renewable) energy is equivalent to dominated by (grid) electricity rather than thermal energy for cooking.

Figure 4. Registered project activities by host party (total: 3 098)

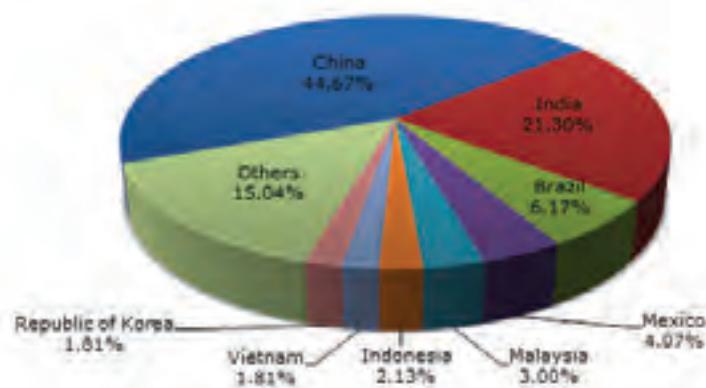
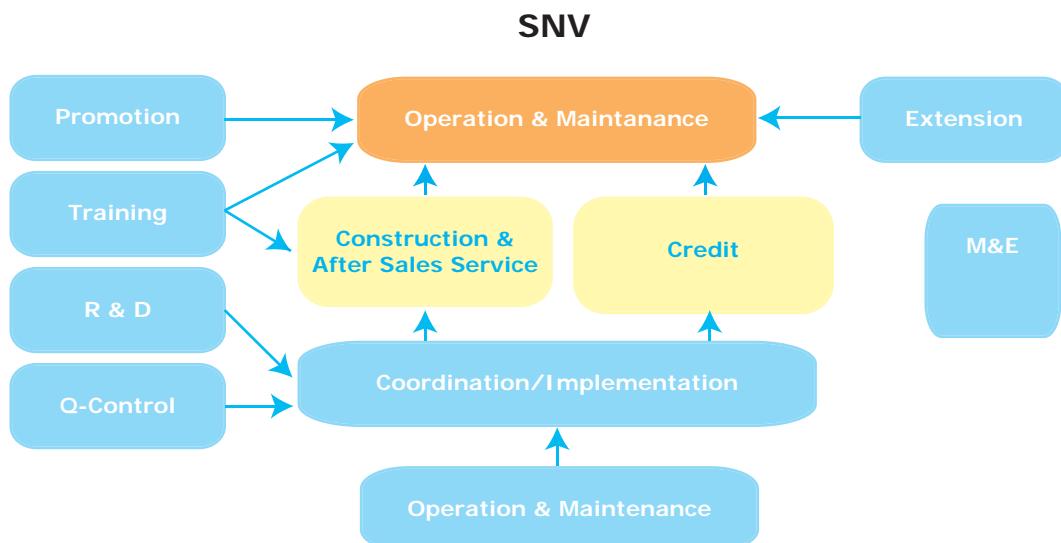


Figure 5. Functions required for National programmes on domestic biogas



## Mass dissemination

In order to address the issue of energy poverty and to mitigate the risks and disadvantages associated with it, energy-poor people need to be provided with access to modern energy services. This can only be achieved by putting in place massive dissemination programmes on appropriate household technologies.

There are a number of such successful initiatives in the Southeast Asian region that have major impacts on hundreds of thousands of households. For example, SNV Netherlands Development Organisation has made significant progress in domestic biogas dissemination. Supported by numerous like-minded donors and organizations, SNV established national biogas programmes in eight Asian (and nine African) countries that enabled the construction of 431,588 domestic biodigesters up till the end of 2011. This resulted in improved livelihoods for approximately 2.5 million people and created jobs for tens of thousands of artisans.

SNV developed a multi-stakeholder sector approach that aims to build on organizational and institutional capacities already available in each country. It is vital to establish and optimize cooperation among all actors involved. SNV helps to strengthen these capacities through its advisory services.

The programmes should finally result in a commercial viable biogas sector, with private companies acting as suppliers to address demand from households that are able and willing to invest. Depending on the country and the size of the digester, and average household invests about US\$350, or 75 percent of the construction costs. The other share is subsidised.

As depicted in figure 5, National programmes on domestic biogas have a range of functions that need to be executed in a coordinated manner. Whereas operation and maintenance of a biogas plant will be carried out by the households, other functions

Table 1. Domestic biodigesters under different national programmes in Asia

Country	Programme commenced in	2011	Cumulative up to 2011
Nepal	1992	19 246	250 476
Viet Nam	2003	23 372	123 714
Bangladesh	2006	5 049	20 756
Cambodia	2006	4 826	14 972
Lao PDR	2006	439	2 405
Indonesia	2009	2 970	4 613
Pakistan	2009	860	1 447
Bhutan	2011	40	40
Total Asia		56 802	418 423

Source: SNV

should be undertaken by other stakeholders like microfinance institutes, training centres, agricultural extension workers and research institutes. In this way the biogas sector is supported by various stakeholders, creating a robust framework for prolonged and massive dissemination. The booklet *Building viable domestic biogas programmes; success factors in sector development* (2009), which is available at [www.snvworld.org](http://www.snvworld.org), gives related details.

## Finance

In 2010 the annual volume of carbon finance transactions was greater than total ODA, which was estimated to be some US\$300 billion (about the same figure as the global subsidy on fossil fuels). According to the International Energy Agency the global investments needed to substantially address energy poverty are estimated to be US\$36 billion per year, out of which less than 10 percent is needed for clean cooking facilities (IEA *et al.* 2010).

Access to capital is a prerequisite for developing dissemination programmes that tackle energy poverty. In order to reach large numbers of households a balance needs to be found between a fully subsidized and a free market approach. The free market approach is not feasible when consumers are able to pay only part of the costs, so public finance is required to subsidize and sustain the dissemination scheme.

When linked to quality assurance systems, subsidies serve as a safeguard to enforce quality standards and are justified by the intrinsic public benefits in the field of environment, welfare and job creation that those technologies generate. Therefore ODA and government funding are needed to support large dissemination schemes.

Besides, households willing to make an investment need microcredit to lower the financial threshold of the initial investments costs. Although a digester is not a commercial investment, it saves households' expenditures on fuel, fertiliser and pesticides and as such there is convincing evidence that biogas-using households have a very low default rate in paying back the microloan. Particularly in Nepal, loans for biogas by microfinance institutes are considered as business as usual.

Carbon methodologies and procedures so far bypass household technologies, due to lack of methodologies and monitoring requirements. This needs to change

and be simplified to allow the uptake of projects that are disseminating household technologies. Also it is evident that upfront investments are needed as carbon revenues take some years to be generated and typically these kinds of projects are not embedded in a capital-rich environment such as that for industries and commercial endeavours. Establishment of guaranteed funds may attract private investors in this underdeveloped and innovative component of the carbon business.

## Positive highlights

There are profound on-going positive developments that point in the direction of including energy-poor households. There are clearly a number of opportunities and developments that help to address energy poverty in the world. To name just a few in random order:

1. Successful and sustainable large-scale dissemination initiatives have already proven to be possible in a number of technologies. Let us learn from and build further on them or replicate them elsewhere. The Ashden Award Web site showcases these success stories.
2. There are innovative organisations like Nexus that link private equity with programmes addressing household energy and aim for carbon development.
3. According to the UN Secretary-General Ban Ki-moon, access to modern energy services has the attention of those concerned with MDGs.
4. The Global Alliance for Clean Cookstoves was launched last year, with high-level political support and aiming at 100 million cook stoves by 2020.
5. ADB manages the Energy for All initiative that aims at providing modern energy services to 100 million people in Asia by 2015.
6. Increasingly bigger companies from developed countries wish to compensate their GHG emissions through renewable energy projects for households for distinct environmental and social benefits.
7. The gender dimension of household energy, climate change and carbon finance is addressed by the lobbying activities of networks like Energia and others.



## Conclusion

Considering its scope and magnitude, the challenge of tackling household energy cannot not be the exclusive domain of specialists and NGOs, but deserves solid inclusion in the common national and international discourse of (renewable) energy, poverty and carbon mitigation.

In order to address energy poverty, massive dissemination programmes are needed to reach those households that currently lack access to modern energy services. To roll out and replicate new and successful programmes, and access public finance like ODA, national budgets are required to expand these initiatives. Inclusion of household technologies for carbon projects will provide new opportunities that may propel further dissemination of household energy technologies. SNV strives to bridge those gaps by linking global policies to household realities.



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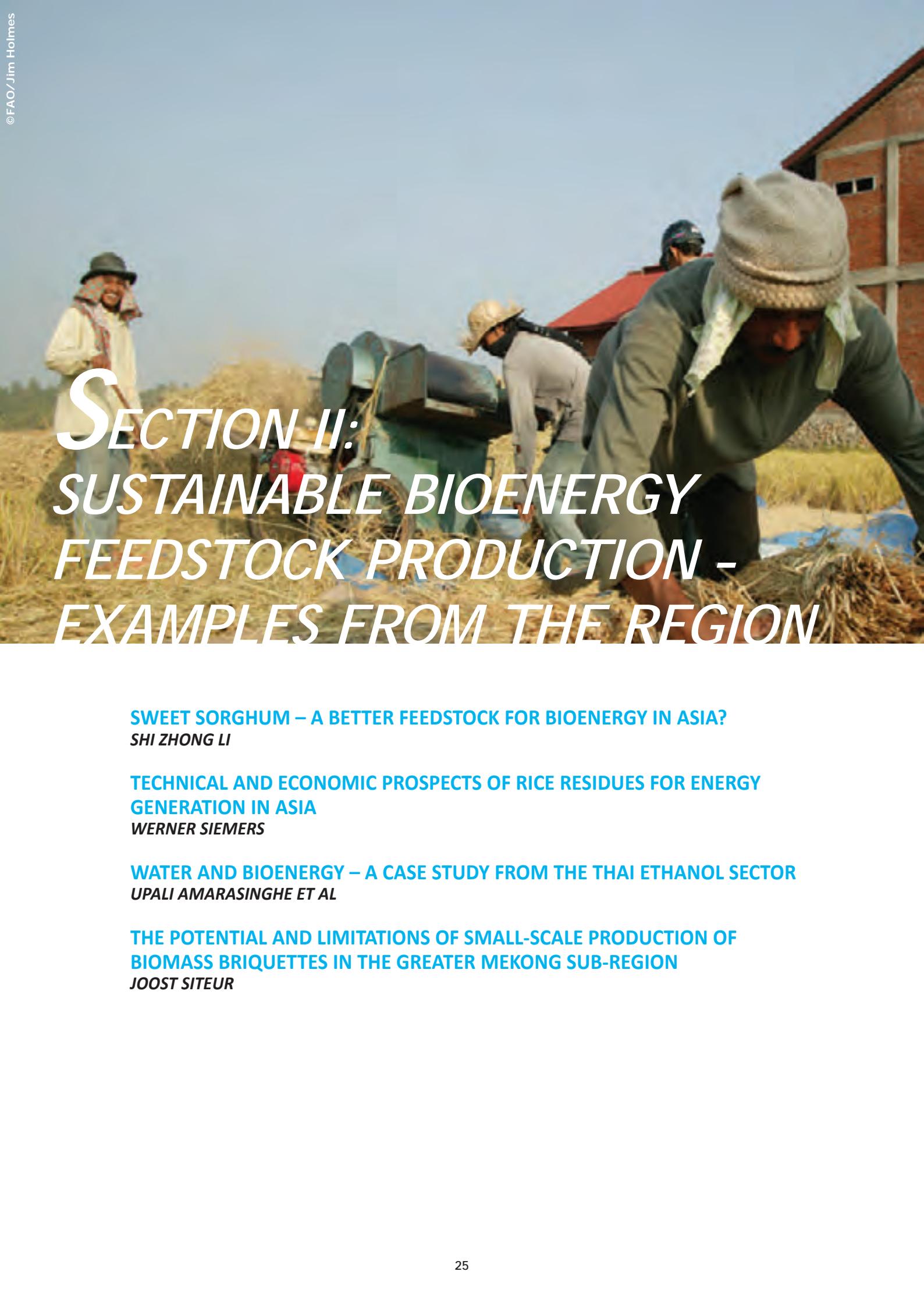
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# SECTION II: *SUSTAINABLE BIOENERGY FEEDSTOCK PRODUCTION - EXAMPLES FROM THE REGION*

**SWEET SORGHUM – A BETTER FEEDSTOCK FOR BIOENERGY IN ASIA?**

**SHI ZHONG LI**

**TECHNICAL AND ECONOMIC PROSPECTS OF RICE RESIDUES FOR ENERGY  
GENERATION IN ASIA**

**WERNER SIEMERS**

**WATER AND BIOENERGY – A CASE STUDY FROM THE THAI ETHANOL SECTOR**

**UPALI AMARASINGHE ET AL**

**THE POTENTIAL AND LIMITATIONS OF SMALL-SCALE PRODUCTION OF  
BIOMASS BRIQUETTES IN THE GREATER MEKONG SUB-REGION**

**JOOST SITEUR**

# Sweet sorghum - a better feedstock for bioenergy in Asia?

Shi-Zhong Li<sup>1</sup>

## Introduction

By the end of April 2011, the price of crude oil had reached US\$125 per barrel, compared to US\$70 in 2010. As the economies of Asian countries are closely related to oil, the International Monetary Fund has reported that if the price breaks through US\$150 per barrel, GDP growth may be affected by around 0.50-0.75 percentage points in China and 0.50 in India (Palit 2011). Many countries apart from China and India are also seriously affected by the energy crisis and have significant greenhouse gas emission problems; in this context policies and plans have been generated to develop biofuel technology, especially second generation biofuels. In May 2011, the International Energy Agency, based in Paris, predicted that the global use of biofuels will reach up to 27 percent by 2050 from today's 2 percent (IEA 2011). Therefore it appears that biofuels have a bright future.



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However, a report by a think-tank in London based on a 14-month long inquiry into the ethics of biofuel technology showed that policies and targets to encourage biofuels had "backfired badly". It pointed out that the rapid scaling up of biofuels contributes significantly to higher food prices and deforestation (Tait 2011). But as the only new liquid energy form for powering motor vehicles (Garcia *et al.* 2011), biofuels continue to be important while fossil energy sources are drying up.

First generation biofuels have caused conflicts between food and energy needs (Gomez *et al.* 2011) while the cost of second generation biofuels is still much higher than fossil energy; thus many technology bottlenecks remain (Mancaruso *et al.* 2011) and the use of non-food crops such as cassava, Jerusalem artichoke and sweet sorghum has attracted considerable attention worldwide (Walker 2011). Tsinghua University, China, has developed a process for producing ethanol from sweet sorghum by advanced solid state fermentation (ASSF) (Shi-Zhong Li and Chan-Halbrendt 2009). This technology was shortlisted for the highest award of Sustainable Biofuel Technology Supplier, World BioFuels Congress in Belgium March 2009. Many countries threatened by the food and energy crisis, such as Ethiopia and South Africa, have shown great interest in this technology. 2009a).

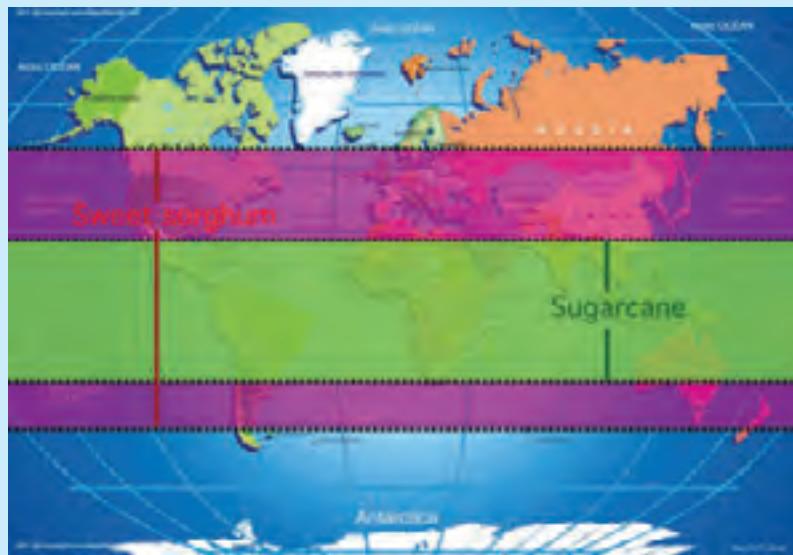
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## The advantages of sweet sorghum and the ASSF technology

### Sweet sorghum has more competitive advantages than other feedstocks

Sweet sorghum can be grown worldwide (Figure 1); water demand is less than one-quarter of the requirements for sugar cane and it can be grown two to three times per year. Thus it is a good crop for semi-arid and saline-alkaline areas, such as those found in Africa (Guigou and Lareo 2011). Sweet sorghum can provide not only fuel and electricity without any wastewater issues, but also grain. Due to advantages such as high yield, suitability for low-quality land, low water requirements and the grain's versatility for both the food industry or bioethanol production, sweet sorghum is surpassing sugar and maize with regard to popularity for bioethanol. It is thought that bioethanol production technology using sweet sorghum as raw material is a bridge from first generation to second generation biofuel, with a ranking of 1.5.

Figure 1. Potential adaptation of sweet sorghum worldwide



## The advantages of ASSF compared with liquid-state fermentation

ASSF, which was developed by Tsinghua University, China, enables sweet sorghum as a promising feedstock for ethanol and other biofuels (Shi-Zhong Li and Chan-Halbrendt 2009)

Solid state fermentation was introduced initially in the early nineteenth century; it was first used to produce proteins and antibiotics (Pandey *et al.* 2000). At that time it was difficult to make accurate models to predict solid state fermentation, so liquid fermentation became much more popular (Yovita 2006). However, solid state fermentation has many advantages compared to liquid state fermentation, such as low energy cost, less wastewater and low cost (Gonzalez and Torres 2003). The author combined sweet sorghum and solid state fermentation together, creating a new and economical way to produce bioethanol from sweet sorghum. Though this is not the first protocol to use sweet sorghum to produce biofuels, it is the most economical one compared to those using sweet sorghum juice (Shi-Zhong Li and Chan-Halbrendt 2009).

In India, Rusni Distillery set up a pilot plant to produce ethanol (40 kilolitres/day) from sweet sorghum stalks

using traditional juice fermentation technology; the process of producing bioethanol generally involves the extraction of juice through crushing of cane, juice pasteurized, fermentation, distillation and dehydration. It takes 28 tonnes of sweet sorghum stalks to produce 1 tonne of ethanol, and the production cost is not competitive with corn and sugar cane ethanol (Ratnavathi and Suresh 2010).

Compared with liquid state fermentation, ASSF has many advantages which make its production cost much lower.

- By using a new kind of yeast isolated by the author's laboratory in Tsinghua University, the fermentation process has decreased to 24 hours with 92 percent ethanol yield, and the pretreatment of raw materials is also much simpler (Shi-Zhong Li and Chan-Halbrendt 2009).
- No press is required in the process flow, and also the operation is simple, so the cost of facilities and human resources is quite low.

- The technology can convert 96 percent of sugar inside stalks into ethanol, while the India Rusni Distillery juice fermentation technology can only use 60 percent of sugar inside the stalks (Juice yield to an extent of 40 percent of cane yield on weight basis, ICRISAT, 2007); ASSF can optimize use of raw materials at lower production cost (Wu and Staggenborg 2010).
- Most importantly, ASSF's low energy consumption for high concentration of ethanol bagasse to generate steam for the distillation of ethanol which can save great amounts of energy in the distillation unit; the energy input and output ratio of ethanol during the production process is 1:23 (Table 1).
- The ASSF process produces much less wastewater as no juice production is required. The residue after distillation can be good cattle feed as it contains a high quantity of protein and yeast (Gnansounou 2005).
- The ASSF process is very simple (Figure 2), that means low capital cost and low educated labor for operation.

The smashed sweet sorghum stems are fed to continuous solid state fermentor for one day time fermentation, the fermented stems are then delivered to continuous solid state distillation tower for separating ethanol, the remained bagasse will be rumen animal feed or boiler fuel. Due to the aforementioned advantages, the production cost of bioethanol is only US\$2.06/gallon, which is very competitive compared to grain and cellulose bioethanol.

## Two models for sweet sorghum ethanol production using ASSF technology

In order to further reduce the cost and meet different needs, the author's group also put forward two models for sweet sorghum ethanol production using the ASSF technology.

The first, the Fuel & Power model, is for areas which lack both power and fuel. In this model, 2 000 hectares of sweet sorghum can produce 10 000 tonnes of ethanol and the residue of the distillation unit can supply 9 million kWh to the national grid from a 2 MW biopower plant. The ethanol production cost of the Fuel & Power model is estimated at US\$503/tonne ethanol (US\$1.94/gallon) at the sorghum stalk cost of US\$25/tonne; the capital cost is around US\$15-17 million for the ethanol plant with a capacity of 10 000 tonnes/year affiliated with a 2.5 MW biopower plant.

The second, the Fuel & Feed model, is for areas where power is not in urgent demand, such as China, the United States and the European Union. In this model, 2 000 hectares of sweet sorghum can produce 10 000 tonnes of ethanol and feed 6 000 cattle; their manure can produce 2.8 million Nm<sup>3</sup> of biogas and 60 000 tonnes of organic fertilizer. The ethanol production cost of the Fuel & feed model is estimated at US\$686/tonne ethanol (US\$2.06/gallon) at the sorghum stalk cost of US\$30/tonne; the capital cost is around US\$9-10 million.

The ASSF technology was also tested on sugar cane (Brazilian sugar-cane ethanol) and sugar beet (EU sugar beet ethanol) to produce bioethanol (Bing Han, et al, 2012). The ASSF process can reduce

**Table 1. Energy balance of ethanol production (based on 1 tonne of ethanol)**

Energy input		Energy output	
Electricity: 373 kWh (GJ)			
Ethanol production 180 kWh (GJ)	1.343 0.648 0.695	1.35 tonnes of pellets (GJ)	19.78
Distiller pelletizing 193 kWh (GJ)			
4.52 tonnes of steam for distillation and dehydration (GJ)	11.92	1 tonne of ethanol (GJ)	29.30
50 tonnes of hot air for drying distiller (GJ)	4.94		
<b>Total (GJ)</b>	<b>18.203</b>	<b>Total (GJ)</b>	<b>49.08</b>



Figure 2. The layout for a 10 000t/a ASSF plant



ethanol production cost considerably compared with traditional juice fermentation technology, and also save on investment in juicing, energy, wastewater treatment and so forth.

The pilot plant with 5 cubic metre, 127 cubic metre and 555 cubic metre rotary drum fermenters is operational in Inner Mongolia. Based on operating data and mathematical simulation, the process package and design of a 10 000 tonnes/year sorghum ethanol plant has been devised.

## Conclusion

Due to the advantages described in this paper, the ASSF technology could help many countries, especially developing countries, to lower their energy dependence, improve their economies and create new jobs without impacting food production. It is thought that this is a technology that can lead to breaking the biofuel deadlock and with improvement of the process, greater benefits for people worldwide.

## Acknowledgement

This work was financially supported by the International Cooperation Project (2010DFA61200) and National Science and Technology Infrastructure Program (2011BAD22B03) supported by the Ministry of Science and Technology (MOST), China.



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# Technical and economic prospects of rice residues for energy generation in Asia

Werner Siemers<sup>1</sup>

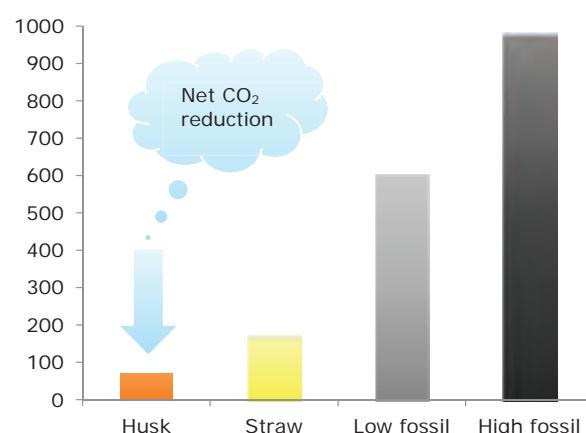
## Introduction

The motivation for considering the energy potentials of agricultural byproducts is manifold. Biomass utilization for energy has been considered carbon neutral because in the combustion of biofuels the CO<sub>2</sub> released was accumulated by photosynthesis. If electricity, heat or fuels can be substituted, reductions of CO<sub>2</sub> emissions are possible. Also fossil energy consumption, and this is in most cases imported energy, might be lowered through use of biomass resources. But the option is only advisable in cases where a surplus of resources exists so natural vegetation is not destroyed or agricultural areas are not overexploited. In this context, rice husks and rice straw are resources with high potential. They are by-products of food production and thus would not interfere in the competition on land for future nutritional demands. In some cases husks or straw are burned on the fields for preparing the next crop causing high local emissions and public disturbance. If used in a 'modern' conversion process for energy, local emissions can be reduced and in certain cases fossil energy use avoided.



Figure 1 gives examples for net GHG reduction taking into account GHG emissions from combustion and fossil energy demand for processing and transport of the biomass resources. In comparison with the fossil energy alternative, high net reductions of GHGs are possible (especially in countries with coal-based electricity). An overview is given on the state-of-the-art of rice residue utilization in India, Thailand, Viet Nam and China representing typical utilization patterns for the region

Figure 1. Comparison of GHG emissions for electricity production from rice husks and rice straw with two examples of fossil-based electricity



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## Characteristics of rice husks and rice straw

Although the plant origin is similar for rice husks and rice straw, their energy potential is quite different. Husks are uniform in size and usually dry. They have been already collected and transported (for milling). In some cases there is a market for rice husks and they are traded. Husks can be converted easily to energy, either to steam or to electricity in biomass power plants. A summary of some key characteristics is given in Figure 2.

Straw on the other hand is bulky in size and needs further processing before being efficiently used for energy (briquetting, pelletizing, cutting etc.). It is generated on the field and has more alternative and traditional uses. In both cases, however, the ash content of rice husks and rice straw is rather high compared to other biomass materials.

**Table 1. Comparison between rice husks and rice straw**

Husks	Straw
Uniform in size	Bulky
Dry	Dry, but sometimes wet
At factory level accumulated	Field based resource
Market access, traded	Only local market
Price structure available	High variation in prices
Direct use for energy (power plant, heat) possible	Needs further processing for efficient energy use
Ash content high	Ash content high

## Potentials for energy use

Four country case studies were conducted during 2008 and 2009. The results of desktop studies are available for China (Ding 2009), Viet Nam (Hien 2009), Thailand (Siemers 2009a) and India (Siemers 2009b). In addition, a summary paper and policy brief were compiled (Siemers 2009c).

### India

The total rice production in India for 2008/2009 was approximately 130 million tonnes per year (Mta). On an average conversion ratio (in India different classifications are used compared to the other three countries) this would give a theoretical amount of 30 Mta rice husks and 100 Mta rice straw.

Out of the 30 Mta rice husks roughly 20 to 30 percent of the volume is used for traditional non-energy purposes such as fodder, fertilizer, bedding and building material. Another 11 Mta are already consumed for energy, traditionally, for rural heat and energy demand, parboiling and milling on a small scale. Consumption also involves the production of rice husk ash through burning of husks (which is not environmentally friendly or energy efficient). Some husks are transported and burned in modern biomass power plants. After rough estimation there is still a surplus of 10 Mta of husks available, one-third of the total potential. The theoretical straw potential is calculated

at 100 Mta per year. Large amounts (nearly 50 percent of production) are demanded by animal husbandry for fodder and bedding material. Another 30 percent must be reserved for domestic purposes, for energy demands and other household needs. The apparent surplus might be in the range of 22 Mta, less than one-fifth. This surplus is available only in the rice-producing areas of India. One power plant has already been built for processing rice straw, but it is closed due to technical issues.

### Thailand

In Thailand average production of rice has reached 30 Mta in recent years. This represents theoretically 6.1 Mta of rice husk and 22 Mta of rice straw.

Traditional non-energy use for rice husks is negligible at approximately 0.3 Mta. Traditional energy use in rice mills and for cooking and heating in households still consumes 1.2 Mta, but is on a downswing. About 1.3 Mta of rice husks are consumed for industrial heat and steam demand in cement or other industries, in most cases as co-firing. Thailand has a functioning feed-in regulation and provides incentives for renewable energy. Under the small power producer scheme a number of modern biomass power plants produces grid electricity (mostly with capacities of 10 MW each). The existing power plants create a demand of 1.7 Mta.



This leaves an apparent surplus of 1.6 Mta, which will soon disappear as two biomass power plants are under construction. Rice husks are already considered scarce in Thailand; there are regional shortages, prices have increased threefold and the husks are transported over long distances.

The situation for rice straw is different. Out of the 22 Mta, 50 percent is utilized. Animal husbandry is the main consumer for fodder and bedding material but there are regional differences. In areas with two or three harvests and where straw has no use, open field burning is common. Quite a few studies and test results propose using rice straw for energy. But markets and logistics are not developed and the present material prices at the factory gate are not competitive enough.

### Viet Nam

Total rice production for Viet Nam stands at 36 Mta. Out of this 6.5 Mta comprise rice husks and another 21.5 Mta rice straw.

Rice husks are widely used for non-energy (fertilizer, fodder) and energy purposes (household cooking, food processing), mainly traditionally and in a small-scale industrial context (brick making, the cement industry). Only a small surplus is available, amounting to some 1 Mta, concentrated in the south in the Mekong Delta. Up to now one modern biomass power plant with 2 MW capacity has been built, but more sites are planned.

Rice straw is utilized for animal husbandry and as organic fertilizer or for mushroom culture. Small amounts are consumed for energy purposes, mainly in the north for heating. The apparent surplus, also

concentrated in the Mekong region, is estimated at 6 Mta. The trade price for straw is high in comparison with other biomass energy sources.

### China

China has total rice production of 189 Mta. This translates to potentials in the range of 38 Mta for rice husks and 200 Mta for rice straw. In China no differentiation is made between husk and straw. Out of the total resources (238 Mta of husks and straw together) some 35 percent is used for fodder (20 percent) and for organic fertilizer (15 percent). Household cooking and heating account for 47 percent. Open field burning is practised with an estimated share of 15 percent of the total resources. This leads to no surplus for modern applications. However, an apparent surplus has been assessed of between 37 and 150 Mta under the assumption that the field burning volume can be shifted to useful energy and that a shift will occur in household energy consumption towards modern fuels, freeing up substantial amounts of rice residues. There are plans for decentralized use (briquetting, pelletizing and gasification) and for centralized utilization in co-generation and power plants.

**Summary of potential assessment:** In the four countries under consideration, differences and similarities are found. Rice husks are used for non-energy purposes but mainly for energy generation. This leads to a reduced surplus situation (Figure 3) of between near zero to zero, 15 percent and more than 30 percent.

The available surplus ratio for rice straw is in general slightly higher, but in absolute figures (Mta) the surplus potential is higher compared to rice husks.

**Table 2. Summary of potential assessment**

	China	Vietnam	Thailand	India
<b>Theoretical Potential</b>				
Rice husk, Mta	38	6.5	6.1	30
Rice straw, Mta	200	21.5	22.0	100
<b>Estimated Surplus</b>				
Rice husk, Mta	See straw	1.0	1.6	10
Rice straw, Mta	37 to 150	6.0	11.0	22
<b>Present Modern Use</b>				
Power Plant, Mta	n.a.	0.016	1.7	2.0 to 2.5

## Economic and institutional implications

### Economic implications

An economic analysis was performed in Thailand (Siemers 2009d) with respect to power production and feed-in to the national grid (€1.00 = THB 48.00). The base case for three different sizes of power plants using husks ends up with a calculated Internal Rate of Return (IRR) of between 8 and 13 percent. This was based on actual realistic rice husk cost of THB1 000/tonne (Table 1). Improvements are possible if rice husk ash could be produced and sold. This could increase the IRR by 2 to 4.5 percent only. Another option is the additional income through the Clean Development Mechanism (CDM) and the sale of certified emission reductions (CERs). This measure alone could increase the IRR to levels of between 12 and 17 percent, thus making the operation attractive. The best alternative, however, is the reduction of resource cost. With only THB500/tonne for rice husks (which was the price a couple of years ago), the final IRR can reach 16 to 25 percent.

Hypothetical results have been calculated for straw-fired power plants, as there is no such a plant in operation. The base case (with the actual market price for straw) is not feasible as only 2 percent IRR can be reached. Additional sales of CERs only cannot solve the problem, as shown in Table 2 with 6 to 7 percent IRR. Two alternatives would result in improved levels of IRR, which could be accepted as financially viable. The first is an incentive of THB1.00/kWh produced (increased from THB0.3/kWh for biomass in Thailand), the second a reduction in straw cost to THB700/tonne only. The latter would be difficult to reach under the present situation, because there are no effective logistical concepts in operation.

### Institutional requirements

Modern energy production calls for appropriate framework conditions. One major aspect is a financial incentive to produce and supply electricity to the national grid. The overview in Figure 4 shows the range of feed-in tariffs for the four locations.

Table 3. Financial analysis for rice husk power plants in Thailand

Description	Rice husk 1,000 THB/t	Additional sales of ash	Additional sales of CER	Rice husk 500 THB/t
Case study 9.9 MW power plant	9.92%	11.27%	12.83%	18.39%
General outline 9.9 MW power plant	13.16%	15.17%	17.22%	25.82%
Case study 22 MW power plant	8.36%	13.13%	11.55%	15.99%

Table 4. Financial analysis for rice straw power plants in Thailand

Description	Rice straw 1,250 THB/t	Adder increase to 1 THB/kWh	Additional sales of CER	Rice straw 700 THB/t
General outline 9.9 MW power plant	2.01%	16.19%	7.38%	19.49%
Case study 22 MW power plant	2.45%	12.89%	6.31%	12.50%

Table 5. Different feed-in tariffs

Feed-in tariffs for biomass	China	Viet Nam	Thailand	India
USct/kWh	3.7 to 5.2	4.0	8.2 to 8.8	3.0 to 4.7



The highest tariff is paid in Thailand for biomass-based electricity production. All other countries offer tariffs of only 50 percent compared to Thailand (based on exchange rates and converted to US dollars) indicating that a successful programme needs an appropriate tariff.

Besides financial incentives it is advisable to rely on a clear regulation for supporting renewable energies and independent power production with components like guaranteed grid access, power purchase agreements, existing policy framework etc. GHG reduction and income through the CDM may enhance the situation further.

## Conclusion

- Rice husks and rice straw are major sources of biomass energy in Asia.
- Their potential is only used to a certain extent in modern applications.
- There are traditional and modern competing usages.
- The situation for husks is more advanced because of technical and economic advantages.
- For efficient straw utilization there is still a need for improvements in logistics and pre-processing.
- Both resources can contribute to more renewable energy and reduced CO2 emissions.
- There is only limited competition for food and some competition for fodder, if these resources are used for additional energy production.

In summary it would be worthwhile taking a closer look into the overall potential for rice residues for energy production. There are still some technical and regulatory issues to address.

## Acknowledgements

Funding for the studies came from the Food and Agriculture Organization of the United Nations.

Sincere thanks to a number of experts, colleagues and collaborators mainly at the Joint Graduate School of Energy and Environment in Thailand during the course of the project.



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# Water and bioenergy - a case study from the Thai ethanol sector<sup>1</sup>

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## Introduction

Modern bioenergy systems are attracting increasing attention from governments in Asia as a potential solution to a range of policy problems related to energy security and sustainable development. Despite growing interest in bioenergy systems, there is still a limited understanding of how their expansion could impact on natural resources such as water. This paper aims to shed some light on the relationship between modern bioenergy development and water depletion using a case study on the biofuel sector in Thailand. This case study also includes an assessment of the impact of biofuel developments on water quality in water systems proximate to bioenergy production facilities in Thailand.



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## Bioenergy in Asia

As rapid economic transformation in Asia has encouraged the once largely agrarian societies of the region to transition from traditional bioenergy to more efficient fossil energy systems, the share of bioenergy used to meet regional energy demands has steadily declined. However, higher fossil energy prices and a growing need for more environmentally sustainable energy sources has led to strong support from regional governments for the development of modern bioenergy sectors. This support for bioenergy has often taken the form of volumetric targets or mandates for a range of bioenergy sources complemented by targeted policies designed to facilitate and support their achievement.

But while recent support for bioenergy has been based on the assumption that it will improve national energy security, reduce greenhouse gas emissions and encourage agricultural and rural development, these assumptions are increasingly being subject to more scrutiny and balanced against the possibility that bioenergy

1 This paper is adapted from Amarasinghe, U., Damen, B., Eriyagama, N., Soda, W. & Smakhtin, V. 2011. Impacts of rising biofuel demand on local water resources in Thailand and Malaysia. Bangkok, FAO.

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could also lead to equally negative outcomes. The greatest potential threat posed by worldwide expansion of biofuel production is the possibility that biofuels will withdraw scarce resources from food production systems and worsen the food security situation of vulnerable populations (Berndes 2002; Peskett *et al.* 2007). Further investigation is required to better understand how bioenergy systems will affect the supply and quality of natural resource stocks and their implications for food production systems and the environment. Water is one such resource.

## Bioenergy and water

More than 1.2 billion of the world's population is already living in water-scarce areas (CA 2007). Increasing demand for irrigation coupled with growing water use in domestic and industrial sectors will increase the number of people at risk from water stress to one-third of the world's population by 2050 (de Fraiture *et al.* 2007). Increasing demand for bioenergy could further accentuate stress on land and water resources (de Fraiture *et al.* 2009). The rate and magnitude of depletion and threat of water system deterioration will vary significantly across regions and countries depending on the size of the bioenergy targets adopted and the key technologies and biomass feedstocks identified. As a result, there is considerable value in undertaking targeted assessments at the national level on the impact of bioenergy policies in terms of expected depletion of water resources and the potential bioenergy production chains to contribute to the deterioration of local water systems.

The remainder of this paper will present the findings from research undertaken by FAO and the International Water Management Institute (IWMI) in 2010 to understand how planned ethanol biofuel (a subsector of modern bioenergy systems) developments in Thailand will affect future water consumption at the national level and water quality in local water systems.

**Table 1. Gasoline and diesel demand in Thailand**

Year	Petroleum gasoline	Gasoline demand in Thailand (MLPD)			Total
		Sugar-cane molasses	Ethanol	Cassava	
2006	7.8	0.9		0.3	9.0
2010	19.0	1.1		1.1	21.1
2015	48.6	1.5		3.9	54.0
2022	79.9	1.8		7.0	88.8

Source: DEDE (2010)

## Water depletion and ethanol biofuel targets – case study in Thailand

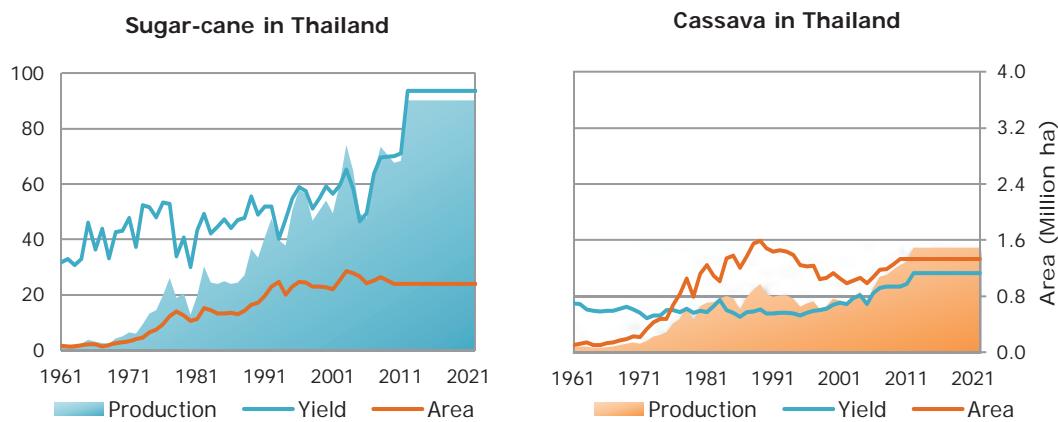
Thailand has a relatively small, but developing biofuel sector. The production of bioethanol for transport purposes in existing alcohol refineries and sugar-milling operations began in 2004. Since then the number of bioethanol refineries has expanded with total production capacity now at 2.575 million litres per day (MLPD) or 940 million litres per year (MLPY).

Thailand has implemented an ambitious policy framework to promote biofuel production and use. Thailand's policy framework for bioenergy and biofuels is underpinned by the Alternative Energy Development Plan (AEDP), which covers the 15-year period from 2008 until 2022. The plan includes targets for a wide range of alternative energy sources including biofuels such as ethanol. As can be seen in Table 1, under the plan ethanol production is to expand from 2.1 MLPD or 770 MLPY in 2010 to 8.8 MLPD or 3,285 MLPY in 2022.

Sugar-cane molasses and cassava are the main feedstocks for ethanol production in Thailand. As a result of the targets, cassava demand for ethanol production is expected to grow from 300 000 tonnes in 2006 to 4 million tonnes (MT) in 2011 and 15 MT in 2022 (DEDE 2010). While sugar-cane molasses is anticipated to account for a decreasing share of Thailand's ethanol feedstock supply over time, production of sugar-cane molasses for ethanol production is still expected to increase from 600 000 tonnes in 2008 to 1.5 MT in 2011 and 2.6 MT in 2021. A key element of Thailand's biofuel targets is the expectation that there will be considerable growth in biofuel feedstock production over the life of the AEDP; particularly during the initial four years of the plan from 2008 to 2012.

Using the water accounting framework developed by Molden (1997), an assessment was undertaken of

**Figure 1. Area, yield and production of sugar cane and cassava in Thailand**



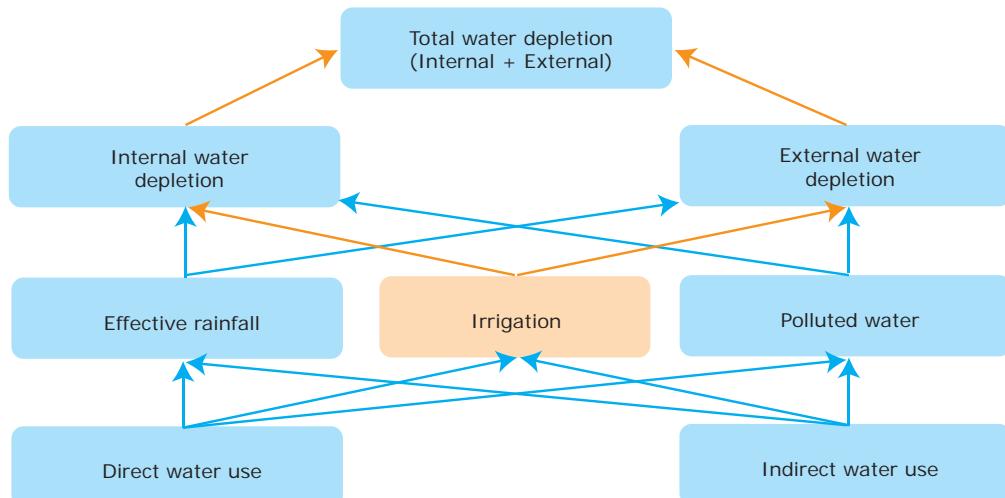
Sources: FAO (2010); DEDE (2010)

expected depletion arising from the achievement of Thailand's ethanol production targets. Water depletion has two components, namely: (i) water depleted within the production area (internal water depletion), and (ii) water embedded in other inputs used in the production process (external water depletion) (Figure 2). The depleted water in both components includes consumptive water use (CWU) from effective rainfall and irrigation as well as water that cannot be used for further beneficial purposes due to quality deterioration. This methodology for assessing internal and external water depletion is comparable to the 'water footprint' analysis employed by Hoekstra (2003) where the CWU from rainfall and irrigation represents green and blue water footprints respectively and polluted water represents grey water footprint. The full methodology and details regarding data and assumptions used to calculate the CWU of ethanol produced in Thailand are available in Amarasinghe *et al.* (2011).

## Case study findings

The total CWU of ethanol production in Thailand was marginal when compared to the country's total renewable water resources (TRWR) of 444 billion cubic metres. The CWU of sugar-cane molasses and cassava ethanol production in Thailand is 1 299 and 1 817 litres of water per litre of ethanol, respectively. Irrigation contributes to only 11 and 0.7 percent in the total CWU of sugar-cane molasses and cassava ethanol production. Feedstock production for biofuel in Thailand is mainly under rainfed conditions. Thus, irrigation demand with respect to the TRWR was minimal. At the above rates of water depletion per litre of ethanol, Thailand's projected sugar-cane molasses and cassava ethanol demand by 2022 will result in irrigation water depletion equivalent to only 0.021 and 0.007 percent of the country's TRWR.

**Figure 2. Components of total water depletion**



Source: Amarasinghe *et al.* (2011)

The need to increase the productivity of biofuel feedstock production in Thailand could result in an increase in CWU and will be difficult to realize in the short term. The Thai Government's current plan to increase ethanol production will require rapid increases in biofuel feedstock production. Between 2010 and 2012 it is anticipated that production of sugar cane will need to grow from 68 to 90 MT, and production of cassava will need to grow from 31 to 37 MT. In the case of sugar cane, in the absence of a significant growth in planted area, significant improvements in sugar-cane yield will be required to meet the plan's targets. This would seem to suggest that the short-term ethanol targets, which rely on strong growth in crop yields, may not be realistic unless additional measures to improve farmer productivity are employed.

### **Impact of biofuel systems on water quality in Thailand**

Although the research indicates that the quantity of irrigation water used for biofuel production is not a major issue, quality deterioration due to increased fertilizer use and wastewater generation could have substantial impact on local water resources. For the purpose of this study a rapid survey was used to assess water and other inputs used in the industrial phases of ethanol production in Thailand. The survey included interviews with factory managers at three production facilities in Ratchaburi, Kanchanaburi and Lopburi provinces.

Increased biofuel production will lead to increased fertilizer use and will also generate large quantities of wastewater including highly toxic spent wash. Although the Thai Government has a zero discharge policy in relation to effluents, spent wash stored in ponds was found to have toxic chemical elements that could contaminate local water resources if they were to escape.

Urea fertilizer used in sugar-cane and cassava production could leach large quantities of nitrogen load to groundwater aquifers. It was estimated that at least 0.868 billion cubic metres of water would be required to eliminate water quality deterioration due to fertilizer use. Although annual natural recharge of groundwater is significantly more than this requirement, localized hotspots could still exist due to spatial variation of fertilizer use and groundwater recharge.

Currently a portion of the spent wash generated by the ethanol industry is used as fertilizer. But excessive use can affect crop yields and deteriorate surface and groundwater resources. Although it is not a major problem at present, full implementation of the AEDP will lead to generation of larger quantities of spent wash. In the case of Thailand, the potential to use the additional spent wash as fertilizer will be complicated by the Thai Government's policy not to expand the crop area of biofuel feedstock crops and the limited number of sugar or palm oil mills and ethanol plants compared to the total crop area. Consequently, much of the spent wash will have to be stored in evaporation ponds. However, treatment of wastewater in ponds at present is ineffective. Excessive leaching of spent wash from ponds to soils and neighbouring water systems threatens the quality of soil, water streams and groundwater resources.

### **Limitations and directions for future investigation**

There is a small, but growing, body of literature on the topic of water depletion, which suggests that there are limitations with the type of 'water footprint' analysis employed in this study. A particular criticism leveled at this type of analysis is that in aiming to produce a single value indicator based on average spatial and temporal conditions it discards important basin specific factors regarding water resource availability and alternative competing uses (Gheewala *et al.* 2011). This study tried to partially address this issue with local assessments of the potential for water quality deterioration in water systems proximate to ethanol production facilities. However, the aggregate assessment of water depletion at the national level does not indicate areas or basins where competition and limited water resources could lead to increased water strain at the local level. This limitation does suggest a direction for further research; particularly the need for more targeted research at the local system level.

### **Conclusion**

As a result of strong economic development the use of traditional biomass energy in Asia is declining. However, a number of governments in Asia are adopting policies to promote modern bioenergy development to achieve a number of policy outcomes including energy security and reduced greenhouse emissions from the energy sector. An expansion of modern bioenergy production implies increased use



of water resources both in the production of biomass feedstocks and the industrial processing of bioenergy. In Thailand, FAO and IWMI have undertaken a national-level assessment to better understand what the impact of the country's biofuel production targets will be on water systems. While water depletion resulting from the targets was minimal at the national level, quality deterioration due to increased fertilizer use and wastewater generation could have substantial impact on local water resources. There are limitations to the methodology used in this assessment and a clear need for further research on this topic. In particular, research on depletion is required at local and basin levels to better understand how competition resulting from bioenergy production and limited water resources could lead to increased water strain at the local level.



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# The potential and limitations of small-scale production of biomass briquettes in the Greater Mekong Sub-region

Joost Siteur<sup>1</sup>

## Introduction

Briquetting of biomass has been discussed as a promising option for poverty reduction and income generation in rural areas for several years. Briquetting is thought to have significant potential in developing countries by upgrading agricultural residues into a more convenient and consistent fuel. However, despite several efforts it seems that briquettes have not been widely adopted in the Greater Mekong Subregion (GMS). This study analyses the major opportunities and constraints associated with small-scale production of wood briquettes in GMS countries. In addition, the viability of briquettes as an alternative source of energy for rural communities is assessed.

In particular, the study provides:

- A review of current briquette production and use in GMS countries, including identification of feedstock material;
- Case studies of existing production facilities in the GMS, to obtain better insight of the viability of small-scale briquetting in the region. Case studies were undertaken for three different types of production facilities in the region; and
- Identification of key factors leading to the success or failure of briquetting operations.



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## Production and use of biomass briquettes

### Previous studies

A literature review showed that very little information is available on volumes of briquette production. Most studies focus on research on the suitability of different types of biomass and the technical aspects of different briquetting machines (for example piston vs. screw-press, improvements to reduce electricity consumption). Research has shown that the preheating of biomass in screw-press briquetting systems is useful to reduce electricity consumption by the briquetting system and to enhance screw life (Grover *et al.* 1996).

In Thailand the market for uncarbonized briquettes is limited and has been steadily decreasing. These briquettes are not attractive for households because existing charcoal stoves do not burn the briquettes efficiently and generate smoke. As for carbonized briquettes, local users appreciate that they do not generate sparks, create minimal smoke, have low ash content, are economical to use and provide a long-lasting fire (Bhattacharya *et al.* 1996). In Chiang Mai, a survey was held among 50 barbecue and grilling restaurants to study the main criteria for choosing carbonized briquettes. The main criteria were cost, heat intensity and duration of combustion (Chaiklangmuang *et al.* 2008).

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## Small-scale production in GMS countries

Several companies that produce briquettes were identified, but overall data on the scale of production are unavailable. An overview of briquetting production in GMS countries, as identified during the current study, is given below.

Plate 1. Location of Case Studies



**Cambodia:** In 2010 a briquetting plant known as the 'Sustainable Green Fuel Enterprise' started operating in Phnom Penh. The plant produces two grades of carbonized briquettes, either from coconut husks or shells, collected from coconut processors in Phnom Penh. The husks are collected free of charge, only incurring labour and transport costs, whereas the shells are bought. The briquettes are considerably more expensive than regular charcoal and most potential customers such as restaurants, are not familiar with the favourable characteristics of briquettes compared to regular charcoal.

**China:** In Yunnan Province a small company that manufactures biomass stoves started producing and marketing biomass briquettes and corresponding stoves in mid-2009. The briquettes are non-charred and are used in gasification stoves. To date, there are no other briquette producers in Yunnan.

**Lao PDR:** No evidence was found of active or past briquetting enterprises in Lao PDR. Reportedly the Technology Research Institute has a small briquetting machine, sporadically used for demonstration purposes.

**Thailand:** Biomass briquettes are widely used throughout the country for barbecuing purposes. In Northern Thailand, several enterprises are supplying briquettes to restaurants and local retailers, using maize cobs, coconut shells and charcoal dust as feedstock. Apart from these small-scale operations, several larger companies produce briquettes from sawdust, rice husks and coconut shells, mostly for the export market and large Thai customers.

**Viet Nam:** According to the Institute of Energy, briquetting is more common in the south, where rice husks are available in larger quantities and coal is more expensive than in the north. Nevertheless, local use of briquettes has decreased significantly compared to 20 years ago, due to the more widespread availability of electricity and liquid petroleum gas (LPG). A handful of small-scale producers is still active, but their numbers are decreasing. The use of charcoal is considerably less common compared to Cambodia and Thailand, so there are fewer opportunities for briquette producers to tap into this market. As in Thailand, several companies produce rice husk and sawdust briquettes for export.

## Small-scale biomass briquetting: case studies

In order to better understand the opportunities and constraints of small-scale briquetting in the region, case studies were undertaken for existing production facilities. Three types of facilities were studied: a member-owned enterprise producing briquettes from maize cobs, three private companies that use a variety of biomass feedstock and a stove manufacturer that has recently started to produce biomass briquettes and corresponding stoves. Each facility was visited by the consultant.

### Cooperative in Phitsanulok, Thailand

Nong Khatao briquetting plant is a member-owned enterprise, located in Nong Khatao subdistrict in Phitsanulok Province. Nong Khatao is home to about 2 000 households, many of which grow maize for a living. The cooperative currently has 89 members, who each had to pay a minimum of 100 baht to buy shares in the cooperative and the right to work in the briquetting operation.



The briquetting of maize cobs was adopted around 1996 as a way to reduce the open burning of cobs in fields, generating serious air pollution and contributing to forest fires. Initially the cobs were densified manually, producing a low quality fuel, but in 1999 the briquetting operation gained serious traction when the community was able to borrow a briquetting machine from the agricultural district office. Subsequently, over 2002-2004 the community received total government funding of THB2.7 million, which was used to buy two briquetting machines and to improve the buildings.

Plate 1: Briquette production at Nong Khatao



The maize cobs are first charred in charcoal pits after which they are ground and mixed with starch and water to improve the cohesiveness and strength of the briquettes. The two briquetting machines are the screw-press type and run on electricity, without any preheating of the fuel. The machines produce hexagonal briquettes with a hole in the centre. The briquettes are sun-dried for about three days before being packaged and sold.

Oddly enough, briquetting occurs in two stages. First, the biomass mix passes through the first briquetting machine, after which the densified material is loosened up and passed through the second machine. According to the cooperative head, this improves the quality of the briquettes. Considering the costs of labour and electricity involved in the briquetting process (see below), the community would benefit from expert advice or research on the premixing of biomass and adjustment of the briquetting machines.

Whereas maize cobs were formerly available in abundance and considered waste, the cooperative

is currently facing a shortage. Previously, maize growers would sell maize grains separated from the cobs, leaving the cobs as waste. In the last three to four years, the larger maize-processing facilities have started to use cobs as fuel, replacing the use of lignite and fuel oil. This means that currently maize growers sell the maize without removing the cob, and the cooperative needs to buy maize cobs from traders at market rates to sustain its operation. Besides buying regular maize cobs, in 2010 the cooperative started buying charred maize cobs. It is also buying regular wood charcoal and experimenting with the mixing of charcoal and charred cobs to be less dependent on maize cobs.

Briquettes are sold to restaurants and food stalls in the towns of Nakhon Thai and Phitsanulok. The current selling price is THB8.00/kilogram (~ US\$0.25 in 2010), which has increased in small increments from THB6.00 in 2002. The community does not maintain an accounting system but can reasonably assess its profitability from the cash flow at the end of the year. As briquettes are more expensive than regular wood charcoal, the cooperative members prefer to use regular charcoal, either bought on the market or self-produced from fruit trees or other sources.

Recently a local university student performed a cost analysis of the production process, keeping track of all expenses for about two months. The analysis showed that labour accounts for more than half of the total production costs (57 percent). It is also interesting to note that starch accounts for nearly as much as maize cobs (11 and 14 percent respectively), despite taking up only 10 percent on a weight basis.

The analysis estimates a profit margin of 12.1 percent and maximum production capacity at 720 kilograms per day. At an assumed average productivity of 70 percent, the community generates nearly THB100 000 in revenue per month, and a yearly profit of THB140 000. Of the annual profit, 5 percent is distributed among the members and the remainder is used for expenses not included in the cost analysis such as building maintenance and vehicle repair.

Initially the cooperative provided significant benefits in the form of reduced smoke and diminished risk of forest fires. Now that the enterprise needs to buy its feedstock, the main social impact is the provision of additional income in an area with few employment opportunities besides farming. As the villagers do not use briquettes for their own energy needs, the

enterprise has no environmental and social impacts associated with the use of briquettes compared to other energy sources. Whereas the cooperative started as a way to overcome the waste problem, it currently keeps operating mainly to provide a source of income to its members. So far the enterprise has managed to cope with the disruption of biomass supply and its current management seems determined and capable to continue its operation. Nevertheless, it is felt that further disruptions on the resource side or changes in management could force it to cease operation.

## Private enterprises in Chiang Mai, Thailand

Several briquette producers market their products in the city of Chiang Mai. The three enterprises studied were identified by surveying local city markets where briquettes are readily available. These briquettes are all char-briquettes, which substitute regular charcoal for grilling and barbecuing. Two of the studied briquetting facilities are located near Chiang Mai city. The third enterprise has its briquetting facility in Phayao Province, roughly 150 kilometres from Chiang Mai, but markets all its produce in Chiang Mai. All three producers were visited and interviewed.

The feedstock for the three producers consists of coconut shells (directly and indirectly) and residue from regular charcoal making. The coconut shells come from southern Thailand, more than 1 000 kilometres away, where coconut growing is more common and, according to the briquette entrepreneurs, produces shells more suitable for briquetting than those available in the north.

One plant purchases the residue from the production of activated carbon by a factory in northeast Thailand, which uses coconut shells as raw material. The residue is in the form of a dry charred powder, which can be easily briquetted and does not require any further drying. The second plant buys the fine residues left over from regular charcoal production in nearby provinces, using wood from fruit trees. The third plant buys the shells directly from the growers in the south, who deliver them to the factory in Phayao, where they are charred and briquetted.

The production process is fairly similar for the three enterprises. The biomass is mixed with cassava starch (roughly 10 percent) and some water, and subsequently fed into the briquetting machine. Each business uses screw-press machines that produce hexagonal briquettes, with a centre hole and a length of about 15 centimetres. The briquettes are usually

dried for a few hours in ovens, using briquettes that are unsuitable for sale, after which they are further sun-dried for about three days.

The briquetting machines run on electricity, which costs around THB4 000 to 5 000 per month. The screws are subject to high pressures and suffer considerable wear and tear, requiring frequent repair. Nevertheless, according to the entrepreneurs, this can be done quickly and cheaply and is not a major issue. Each plant has a maximum production capacity of around 30 tonnes per month. Depending on sales actual production can fluctuate from 5 to 30 tonnes. Nevertheless, each enterprise reports an average production of around 20 tonnes per month.

Each enterprise sells the briquettes through two channels: retail, via a network of shops and markets, and wholesale to restaurants. In wholesale form, briquettes are delivered in bags of around 20 kilograms for THB240-300 per bag to large customers such as Korean-style barbecue franchises and other restaurants. At the retail level, briquettes are sold for about THB8.00 /kilogram to shops and market stalls, which resell them for THB10 to 12.

Because of differences in supply of biomass, production process and sales' channels, profit margins vary among the three enterprises, from 20 to 35 percent. Profit margins for the coconut shell briquettes are lower, presumably because of the greater distances and associated transport costs. Profit reportedly fluctuates between THB40 000 and 60 000 baht/month.

Each of the entrepreneurs was fairly confident about the future of the business. The traditional high demand for charcoal and the superior quality of the briquettes over regular charcoal seem to ensure continued strong sales. Nevertheless, the business seems to be fairly competitive and some entrepreneurs have tried and failed over the years. According to the entrepreneurs, marketing skills and consistency of quality are among the chief success factors. Their main areas of concern are control of production costs, heavy seasonal fluctuation in demand and stability of supply and price of the biomass feedstock.

The entrepreneurs would be interested in support to reduce the expenditure on electricity and other inputs. As in the case of Nong Khatao, starch is a major cost item and the entrepreneurs try to minimize its use to keep production costs low.



Plate 2: Rongxia Briquetting Machine



## Stove factory in Kunming, China

Rongxia Stove and Cooker Appliances Co. Ltd designs, produces and markets high-efficiency stoves for solid fuels such as coal and biomass. Most stoves not only use biomass as fuel, but can also be used in combination with coal. Currently the company has 22 different types of stove and is one of the main suppliers of improved biomass stoves in rural western China.

Encouraged by government programmes promoting the use of agricultural residues, in 2009 the company started exploring briquette stoves and decided to build its own briquetting machine and produce the briquettes as well. Rongxia currently has briquette stoves in three sizes, each using the same technology. The stoves are gasification stoves, using an external electrical fan for controlled air supply. The briquettes are mostly made from sawdust, given away for free by a nearby furniture factory with Rongxia only incurring labour and transport costs. The company's briquetting machine has a production capacity of 70 to 80 kilograms per hour. Unlike most other briquettes described in this study, Rongxia's briquettes are not charred, round in shape and thin (less than 1 centimetre in diameter).

The marketing of Rongxia's briquettes and stoves is still at an early stage. As a test phase, the stoves have been used by five restaurants for several months, generating positive feedback. The briquettes cost RMB0.5 per kilogram (~ US\$0.07), roughly eight times cheaper than gas or diesel, which makes restaurants and other

large-scale users the best target group. Another target is the relatively well-off households in peri-urban areas that have no access to gas connections common in urban areas, but would prefer the convenience of the gasifier stoves over regular fuelwood.

The initial feedback from the restaurants using the briquette stoves suggests that the combination of selling stoves and briquettes provides good prospects for Rongxia. The company already has a good track record for quality in the stove market, giving potential customers confidence in the product.

## Conclusions

### Use of briquettes

The use of non-carbonized briquettes gained some popularity in the 1980s in the region, but in recent years their use has been declining steadily, most probably due to the increasing availability and affordability of LPG and electricity. As for carbonized briquettes, they are only used for grilling and barbecuing, concentrated in urban areas, particularly in Thailand. They are mostly used by restaurants and food shops that prefer the briquettes over regular charcoal because of their superior combustion properties. In addition, a sufficiently large number of urban households is willing to pay a higher price for the same reason, creating a fairly high demand at the retail level as well.

With regard to the viability of briquettes as an alternative source of energy for rural communities, no evidence was found of the use of briquettes in rural areas in the region. Briquettes are more expensive than regular fuelwood or charcoal. For this reason, in rural areas no households seem to buy briquettes for domestic cooking. Even the members of the rural community in Nong Khatao who are very familiar with briquettes prefer to use regular fuelwood or charcoal because of the lower costs.

### Biomass resource

As is the case for all biomass energy projects, the security and stability of the biomass resource are crucial factors for the long-term success of a briquetting operation. Studies on biomass briquetting often start from the assumption that this would be an opportunity for rural communities to make use of their agricultural residues, supposedly available in abundance. The case studies show that this is certainly not the only, and possibly not the most viable model. Industrially-generated residues, even at large distances, can be a viable feedstock for briquetting,

as long as long-term supply is sufficiently stable and secure, in terms of pricing, availability and quality. The case of Nong Khatao shows the initial abundance of a resource is no guarantee for its long-term availability.

### Technology

The screw-press is the most commonly used technology for biomass briquetting. Machines are either bought or are self-made. Screws are subject to high wear and tear, requiring frequent repair; according to the entrepreneurs interviewed this is not a major issue. This suggests that technology is not as crucial as suggested by some earlier studies that identified technology as a major barrier. This may be because significant progress has been made since these studies were carried out, or because other factors are more relevant to the long-term viability of a briquetting operation.

Nevertheless, the entrepreneurs were unaware of research on the preheating of the dye and biomass before briquetting, in order to reduce production and maintenance costs. As starch is a major cost item, entrepreneurs would most probably benefit from the sharing of results of previous research.

### Success factors

Overall it can be concluded that the market for biomass briquettes within GMS countries is concentrated in specific areas and sectors. At the macro level the opportunities for small-scale briquette production are limited. Nevertheless, when targeting the right areas and sectors, the production and marketing of briquettes can be a lucrative business under the right conditions.

From the case studies, the following main factors were identified as being crucial for the success of a briquetting operation:

- Stable supply of biomass feedstock;
- Strong and stable demand;
- Quality of briquettes; and
- Marketing and entrepreneurial skills.

## Policy recommendations

### Careful targeting of promotional activities

Efforts to promote briquetting are often driven by technology initiatives and the supposed availability of agricultural residues. In fact, as the case studies show, the market for briquettes is highly site- and sector-specific and the availability of biomass resources may be constrained by several factors. Indiscriminate promotion of briquetting without proper demand and resource studies is likely to fail and should be avoided.

### Financial incentives

In most cases, briquettes are relatively expensive compared to the currently most commonly used fuel (such as carbonized briquettes vs. charcoal). To stimulate the wider use of briquettes, it may be helpful to introduce financial incentives, such as tax benefits, subsidies and loans to producers. Because of the site- and sector-specific aspects, these need to be designed and targeted carefully. What works in one setting, may not work in another.

### Dissemination of research

A substantial amount of research has been conducted on briquetting technologies, but it seems that this does not always reach briquette producers. Wider dissemination activities, as well as the distribution of research in local languages, would be useful to further propagate research outcomes.



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# *SECTION III: HOW TO MAKE MORE EFFECTIVE POLICIES AND FINANCING ARRANGEMENTS FOR RURAL BIOENERGY*

**CHALLENGES AND OPPORTUNITIES FOR FINANCING RURAL BIOENERGY PROJECTS**

**AURELIE PHIMMASONE ET AL**

**CHALLENGES ASSOCIATED WITH REPLICATING SUCCESSFUL BIOENERGY PROJECTS IN THAILAND**

**WERNER SIEMERS  
APICHAI PUNTASEN ET AL**

**POTENTIAL FOR SOCIAL INDICATORS TO GUIDE BIOENERGY POLICIES**

**SITTHA SUKKASI**

**USING MICROFINANCE FOR FARM-/HOUSEHOLD-LEVEL BIOENERGY TECHNOLOGIES**

**RIAZ KHAN**

# Challenges and opportunities for financing rural bioenergy projects

Aurelie Phimmasone<sup>1</sup> and Nguyen Huong Thuy Phan<sup>2</sup>

## Introduction

Through earlier activities jointly developed by FAO and SNV in Lao PDR and Viet Nam in 2009, the lack of affordable and accessible financing was identified as a key obstacle to the development of the bioenergy sector in these two countries. Therefore FAO commissioned two studies to further investigate the financing of bioenergy. The studies were conducted simultaneously by the Lao Institute for Renewable Energy (LIRE) and the Asian Institute of Technology in Vietnam (AIT-VN).

The objectives of these studies were to:

- Review the institutional and policy framework;
- Review financing options for bioenergy projects;
- Identify barriers to bioenergy financing and potential solutions to overcome them; and
- Provide recommendations for policy interventions.

This paper summarizes the main findings of the two studies, highlighting common issues and constraints in the two countries.



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## Methodology

The study's methodology involved four main steps:

- a. A desk study of relevant documentation and secondary data review to provide a picture of the current policy and institutional framework, as well as projects in place and under development.
- b. Interviews with selected key stakeholders from government agencies, development groups and financial institutions to gather information on existing investment channels including opportunities and constraints.
- c. Interaction between the two study teams to discuss common issues and approaches.
- d. Stakeholder consultation workshops in each country to consult government agencies, public and private banks, investment groups, project developers and other stakeholders on the status of bioenergy development and solutions to improve access to financing.

## Environment for bioenergy financing

This section provides an overview of the overall situation of renewable energy (RE) financing in each country, reviewing policies, key actors and available financing mechanisms.

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## Policies and strategies

As of yet, strategies for developing RE are generally part of overall policies and strategies for energy, the environment and rural development. Currently both countries are in the process of developing a specific strategy for RE development.

Table 1. Strategies for RE development

Lao PDR	Viet Nam
<p><b>National Socio-Economic Development Plan (NSEDP) 2006-2010:</b></p> <p>RE not clearly defined as a priority, but the plan highlights the need for "promoting the development of environment-friendly private sector products such as (...) technologies that are energy efficient and clean". The NSEDP focuses mostly on electricity generation for export, as a source of revenue, and to achieve 90% electrification by 2020. The draft NSEDP 2011-2015 reiterates the objective to "develop hydropower sources and renewable energy in order to supply energy to production sectors and society, and become the battery of ASEAN" (MPI 2010).</p> <p><b>Renewable Energy Development Strategy (October 2011):</b></p> <p>Refers to biofuels, biomass, biogas, solar and wind power also with a strong emphasis on hydropower of less than 15 MW in size.</p> <ul style="list-style-type: none"> <li>▪ Objective of 30% share of RE in energy consumption by 2025;</li> <li>▪ Substitute tentatively 10% of the transportation fuel demand from biofuels by 2025;</li> <li>▪ Financial incentives for RE projects, e.g. import tax exemption, tax reduction/exemption on profits, VAT, and repatriation of profits, and possible subsidies on unit product price, and longer land leasing term;</li> <li>▪ Creation of a public Renewable Energy Fund;</li> <li>▪ Small hydropower: Exemption from concessional agreements and royalties, competitive bidding, non-discriminatory connection to national grid, and preferential loans from state-owned commercial banks;</li> <li>▪ Proposed establishment of a new division at the Department of Electricity (DOE), in the Ministry of Energy and Mines (MEM) called Institute for Renewable Energy Promotion (IREP)</li> </ul>	<p><b>National Strategy on Energy Development</b> up to 2020 with a vision towards 2050:</p> <ul style="list-style-type: none"> <li>▪ RE as share of total commercial primary energy to 5% in 2020 and 11% by 2050;</li> <li>▪ Diversify investment and business models to develop a competitive energy market.</li> </ul> <p><b>National Power Development Master Plan</b> 2006-2015 with outlook to 2025:</p> <ul style="list-style-type: none"> <li>▪ Additional electricity capacity from RE of 2 451 MW by 2015 + 1 600 MW by 2025;</li> <li>▪ 400 remote communes in northern and central highlands and islands as target recipients of electricity from RE;</li> <li>▪ Import tax exemption for wind turbines and solar panels.</li> </ul> <p><b>Strategy and Master Plan for Renewable Energy Development</b> up to 2015 with an outlook to 2025 (draft):</p> <ul style="list-style-type: none"> <li>▪ Incentives for small hydro, wind, solar, geothermal power, biomass and biofuels;</li> <li>▪ Creation of a Renewable Energy Development Fund (REDF);</li> </ul> <p><b>Scheme for Biofuel Development</b> up to 2015 with a vision to 2025:</p> <ul style="list-style-type: none"> <li>▪ Priority loans and land support to international and domestic investors;</li> <li>▪ By 2025: Target of 1.8 million tonnes of ethanol and vegetable oil output or 5% of oil and gasoline demand.</li> </ul> <p><b>National Rural Electrification Program:</b></p> <ul style="list-style-type: none"> <li>▪ Diversify ownership forms and promote decentralized RE electricity generation offered to rural households</li> <li>▪ Programme has triggered small hydropower development since 2005.</li> </ul>



## Key actors

The main actors in RE are government agencies, state-owned energy companies, international organizations and private sector developers and investors.

Table 2. Government agencies

Lao PDR	Viet Nam
<p><b>Ministry of Energy and Mines (MEM):</b> Key government body for RE. At the national level, MEM has primary responsibility for policy formulation and strategic planning, as well as the preparation and implementation of legislation and regulations related to the power sector and RE.</p> <p><b>MEM departments working on RE:</b></p> <ul style="list-style-type: none"> <li>▪ Department of Electricity: Main roles are to prepare strategic planning for the power sector and regulate the electricity sector;</li> <li>▪ Department of Energy Promotion and Development (DEPD): Supports the development of power plants and coordinates with Independent Power Producers (IPPS), mainly large hydropower and large-scale foreign investment.</li> </ul> <p><b>The former Sciences Technology and Environment Agency (STEA) has been divided into two separate institutions:</b></p> <p><b>Ministry of Natural Resources and Environment (MONRE):</b> Responsible for water use and environmental permits, as well as the implementation of the National Strategy and Action Plan on Climate Change (NSAPCC). Designated National Authority (DNA) for CDM projects.</p> <p><b>Ministry of Science and Technology (MOST):</b> Recently established this ministry works on policy formulation and planning across all sectors. Under its umbrella are regrouped different research institutions, but coordination among them is low (Technology Research Institute, Engineering and Renewable Energy Centre, and Renewable Energy and Materials Institute (REMI)).</p>	<p><b>Ministry of Industry and Trade (MOIT):</b> Responsible for preparing laws, policies and regulations related to RE, as well as the appraisal and monitoring of RE investments through the issuance of licences and other legal documents. MOIT also has the task of supervising state-owned energy companies such as EVN and Petrovietnam.</p> <p><b>Departments working on RE:</b></p> <ul style="list-style-type: none"> <li>▪ Department of Energy (DOE) develops and implements policies and programmes;</li> <li>▪ Department of International Cooperation coordinates programmes with other countries and international organizations.</li> </ul> <p><b>Ministry of Finance (MOF):</b> Borrows from international development funding organizations and then re-lends the money to public and private investors for energy project financing or re-financing, e.g. JICA's Energy Efficiency and Renewable Energy Program (EEREP) or the EIB's Climate Change Program.</p> <p><b>IE:</b> Key actor in RE policy with mandates of research, consultancy and promotion of international cooperation in power, gas, coal and RE. IE has been commissioned by MOIT to conduct studies on RE policies and strategies including feed-in tariffs and guarantee schemes as well as master plan formulation.</p> <p>IE is also active in assisting investors and financiers with assessment of RE potential, conducting feasibility studies and providing technology transfer assistance. IE is an investor through ownership in the Vietnam Renewable Energy Company (REVN).</p>

Table 3. State-owned enterprises

Lao PDR	Viet Nam
<p><b><u>Électricité du Laos (EdL):</u></b>  100% state-owned corporation under the jurisdiction of the Ministry of Energy and Mines. It owns and operates the country's main generation, transmission and distribution assets. It also manages electricity imports into its grids and exports from its stations, whilst promoting and developing sources of power supply.</p> <p>It implements government power projects, and represents the government as a shareholder in IPPs. It promotes a commercial approach to off-grid electrification, but the Rural Electrification Division directly manages off-grid RE.</p> <p>EdL recently established EDL-Generation to own and manage its generation assets. EDL-Gen is 75%-owned by EdL, while the rest of the shares were issued through an IPO in January 2011. EDL-Gen is the first security to be traded on Lao PDR's new stock exchange that started operating in 2011.</p> <p><b><u>Lao State Fuel Company (LSFC):</u></b>  100% state enterprise under the Ministry of Industry and Commerce. The company has more than 150 gas stations around the country and annual sales of 150 million litres of petroleum products.</p>	<p><b><u>Electricity of (EVN):</u></b>  Formerly a state-owned monopoly electricity producer and distributor, in 2004 EVN was spun off and is now a joint stock company called the Vietnam Electricity Group with subsidiary power plants, distribution and retaining companies. The majority of shares in EVN still belong to the government with primary supervision from the MOIT.</p> <p>As the main electricity authority, EVN is both a producer and a buyer for RE. EVN has invested in small hydropower schemes below 30 MW and buys electricity from other RE projects to supply remote areas.</p> <p><b><u>Oil and Gas Corporation (Petrovietnam):</u></b>  Invests and implements activities related to petroleum. Related to these functions, Petrovietnam invests in biofuel projects as a producer, a buyer and a distributor. Biofuels are to be added to gasoline and diesel to partially replace the use of fossil fuels.</p> <p>The biofuel strategy includes three main activities: feedstock securing, production &amp; blending, and transportation &amp; distribution.</p> <p>As a producer, Petrovietnam established several biofuel production and distribution projects including feedstock farms, refinery plants throughout the country and three biofuel plants in North, Central and , built in cooperation with foreign companies. Petrovietnam is currently the largest domestic producer and distributor of biofuels in Viet Nam.</p>
	<p>Note: The energy sectors in Lao PDR and Viet Nam remain dominated by public ownership. The main areas of RE activities are therefore led by public utilities.</p>

## International organizations and donor programmes

International assistance for RE development comes in the form of Official Development Assistance (ODA), grants and soft loans. The funding is either earmarked for specific RE programmes or for more general programmes linked to energy efficiency, energy for poverty reduction or climate change mitigation. A large part of international assistance is used to finance grid extension and rural electrification using RE.

In Lao PDR the most relevant programmes include the Rural Electrification Program (REP I & II), operating under the Ministry of Energy and Mines and supported by the World Bank, the Biogas Pilot Program (since 2007) operating under the Ministry of Agriculture and Forestry funded by the Netherlands with technical assistance provided by SNV, and the recently launched Energy and Environment Partnership Program With the Mekong Region (EEP Mekong) (2009-2012) funded by the Ministry of Foreign Affairs of Finland and the Nordic Development Fund. A new EEP three year Phase (up to 2015) is under planning.

In Viet Nam, the World Bank operates the Vietnam Renewable Energy Development Project in cooperation with MOIT and four commercial banks, while the Ministry of Agriculture and Rural Development (MARD) has been managing the Domestic Biogas Program since 2003 with funding from the Netherlands and technical assistance by SNV.

## Financial institutions and investors

In Lao PDR, the banking sector is dominated by the four state-owned banks, accounting for more than 60 percent of all bank loans. Otherwise, there are a number of private commercial and international banks. None of the banks have a formal policy on RE but several banks have been involved in the financing of medium and large hydropower projects. The Agricultural Promotion Bank (state-owned) has been involved in financing biogas projects (such as household biogas biodigesters).

In Viet Nam, the four largest banks are state-owned or majority state-owned, accounting for 65 percent of domestic lending. They are involved in RE through the on-lending of a loan provided by the European Investment Bank. Commercial banks are involved in RE through the World Bank's Renewable Energy Development Project.

The Mekong Brahmaputra Clean Development Fund (MBCDF) is the first closed fund focused on clean technology (including RE) in the Mekong River Region. Launched in July 2010, it is managed by Dragon Capital and has attracted commitments from international development financing institutions such as the Dutch development finance company FMO, the Asian Development Bank (ADB), FinnFund and BIO. It invests in hydropower, biomass power, wind and solar energy, with investments ranging from US\$1-7 million. In January 2011 it made a US\$3.36 million investment in the newly listed EDL-Gen in Lao PDR.

## Developers and entrepreneurs

In Lao PDR a number of foreign companies and funding agencies invest in large-scale projects (e.g. hydropower plants for export) or acquire equity in local small or medium projects such as solar power, biofuel and hydropower for domestic consumption. There are a few small local enterprises working on the provision of energy services using RE technologies, the main ones being Sunlabob and the Provincial Energy Services Company.

In Viet Nam private RE investors are foreign and domestic companies that invest in hydropower, biogas, wind, biofuel, solar water heating, geothermal and other schemes. Domestic enterprises invest in small hydropower based on the Build-Operate-Transfer (BOT) or Build-Operate (BO) models for selling electricity to the grid. Similar models are used for biofuel and biomass production. Some domestic companies include Solar Energy Co. Ltd., Hoang Khang Group (biofuel), Nguyen Chi Co. (biofuel, biomass), New Energy Co. Ltd. (solar), BK Investment and Development of Solar Energy, and Greenfield (biomass, biofuel, hydropower).

## Financing mechanisms

Examples of the most typical and relevant forms of RE financing in both Lao PDR and Viet Nam, segregated between types of financing are described below.



## Lao PDR

ODA is the most common form of financing for RE projects, with most of the funding directed towards hydropower development. There are a few private sector initiatives, particularly in industrial biogas, but as of yet they seem to be an exception.

### Grant funding

- Hybrid PV/hydropower system in Oudomxay Province supplying electricity to ten villages and 520 households, with a photovoltaic (PV) component of 100 kW. Completed in March 2005, this project was funded by NEDO Japan.
- Household and community PV systems throughout the country installed by Sunlabob and others as part of rural development projects and typically financed by grants from various international development organizations.
- Several microhydropower (<100 kW) projects, either refurbished or newly built, for rural electrification or grid connection, implemented by companies including Sunlabob.
- Variety of solar-powered water pumping or purification and PV-based battery charging stations installed by Sunlabob. Furthermore this model was successfully extended by the same company to solar recharged battery lanterns, with the successful implementation of 2000 lanterns in Bottom of Pyramid (BOP) communities in Laos.

### Public-private partnerships

- Rural Electrification Program (REP): Consisting of three phases and financed by the World Bank, and implemented jointly with EdL and MEM, one of the objectives is to provide rural households with a Solar Home System (SHS) on a hire-purchase basis (i.e. rent-to-buy) with a repayment period of five to ten years. The first two phases connected around 15 000 households.
- Rural Electrification Fund (REF): A component of the REP, the fund aims to finance IPP projects, but so far no IPP projects have been financed by the fund. In order to overcome institutional and financial risks, the IFC and MEM are developing a lease-purchase

mechanism for microhydropower, in which developers would make the upfront investment and would pay a fixed lease for five to ten years.

- Biogas Pilot Program (BPP): Aims to establish a sustainable market for household biogas digesters as a substitute for fuelwood and charcoal. The programme is funded by the Netherlands, financing the technical assistance and advisory role of SNV and a fixed subsidy to households for the installation of a digester. The Agricultural Promotion Bank has recently approved loans to households for the initial capital cost of the biodigester systems.

### Private financing

- Industrial Biogas: Several projects have been developed to generate biogas from wastewater at industrial facilities. The Lao Brewery Company (LBC) project, which is the first CDM project in the country, uses biogas to substitute for Heavy Fuel Oil (HFO) for steam generation. The project was privately financed by LBC with support from International Finance Corporation (IFC), which is part of the World Bank Group. Other projects include the Thai Biogas Energy Company (TBEC) BOOT project at a starch plant operated by the Laos-Indochina Group, and projects at a feed mill and piggery of C.P. Laos Co. Ltd., a subsidiary of the Thai company Charoen Pokphand Foods PCL.
- Biofuel: Several companies are active in developing plantations for biofuel production, mostly based on *Jatropha curcas*, either for export or local use. So far, production is limited and some companies face issues with yields and establishing relations with farmers.
- Solar Home Systems (SHS) rental: Between 2003 and 2009 Sunlabob offered solar home systems to rural households through a rental scheme under which end users paid a monthly fee to rent the PV system. Largely financed by the company, around 4 800 SHS were installed, of which around 3 000 units were returned after the rental scheme was terminated. The scheme was discontinued due to competition from the REP, as well as households' limited ability to pay for the service and the high cost of the training of village energy committees and technicians.

## Viet Nam

RE investment is on the rise due to the government's determination to stimulate RE development and global trends on securing a more sustainable energy supply. The number of projects, investors and financiers in Viet Nam has increased and financing channels have become more diverse. One noticeable trend has been the increasing participation of the private sector. As an indication of the pace of development, the monetary value of currently planned projects in aggregate exceeds the total investment to date in Viet Nam's RE sector.

### Grant funding

Several projects have been developed with grant funding from foreign donors, in particular using PV. For example, PV systems ranging in capacity from 500 to 1 500 Wp have been installed in the southern region in households, hospitals, schools and village communities (ABCSE 2005). Other activities include the Fondem-Solarlab rural electrification project (1990-2000), a rural electrification programme conducted by Solarlab in cooperation with Atersa (2006-2009) and a hybrid system with 100 kWp of PV and 25 kW of microhydropower in Central Viet Nam funded by Japan (Trinh Quang Dung 2010).

### Public-private partnerships

- Domestic Biogas Program (2003-2012): Implemented by MARD and SNV, with funding from MARD and the Netherlands, as well as contributions from households. Farmers installing a biodigester receive a fixed subsidy of about US\$60 regardless of system size, equivalent to 12 percent of the total cost, with the farmers investing the rest. The payback period of a digester is about two to three years. The programme celebrated the milestone of 100 000 units in December 2010.
- The World Bank's Renewable Energy Development Project (REDP, 2009-2014): Debt financing for RE projects which generate electricity to connect to the national grid including small hydropower (< 30MW), wind power, biomass and other schemes. Loans are provided via participating commercial banks. The interest rate and other details are negotiated between the bank and the project and most often follow market interest rates rather than a subsidized one. The maximum funding period is 12 years and

up to 80 percent of total investment capital, with an expected IRR of  $\geq 10$  percent. So far, hydropower seems to be the only technology that can satisfy the banks' commercial viability requirements.

- Credit Program for Energy Efficiency and Renewable Energy, Vietnam Development Bank (VDB): A three-year programme to provide debt financing to clean energy projects, supported by a loan from the Japanese Government. The total budget is US\$40 million, with US\$30 million for energy-saving projects and US\$10 million for RE, including small and medium hydropower, wind, solar, geothermal and biomass schemes. Loans constitute up to 85 percent of total investment with a maximum term of 20 years with a five-year grace period. Interest rates are 6.9 percent per annum for loans in Vietnamese dong, and 5.4 percent for US dollar loans. The Vietnamese Government owns 100 percent of the VDB, under the Ministry of Finance.
- The European Investment Bank (EIB) has provided a €100 million framework loan that will make available long-term loans at attractive interest rates to RE and energy efficiency projects. Loans are provided via four state-owned banks.

### Private financing

- Biomass power: Several biomass power generation projects have been developed at privately owned facilities, such as bagasse cogeneration at around 40 sugar companies throughout the country, and rice husk co-generation and gasification in Southern Viet Nam.
- Industrial biogas: Several companies are active in developing industrial biogas, either as turn-key or BOOT, and often involving revenues from CDM or other carbon-offset mechanisms. Two projects under development include the Dong Xanh Joint Stock Co.'s project at an ethanol plant in Quang Nam Province with an investment of US\$5.3 million, and CDM-based projects in An Giang Province by Hoai Nam Hoai Bac.
- Biofuel: Investments in biofuel come from both public and private sectors, but so far investments from Petrovietnam surpass private sector investments. The latter include

the Green Field ethanol plant in Quang Nam Province, the first bioethanol production plant in Viet Nam, operational since 2008 (Nguyen Phu Cuong 2009), and Saigon Petro's cassava-based ethanol plant operational since 2009. In addition, more than 50 000 hectares of dedicated Jatropha plantation are under development (AITVN 2010).

- Solar water heating: Commercially viable with households and businesses willing to invest in solar water heaters due to savings on electricity bills. Heaters are produced locally by more than ten small and medium enterprises (SMEs).

## Main findings

Overall, the studies identified several positive trends and it can be concluded that the outlook for RE is fairly positive in both countries. However, it should be noted that the focus is on power generation and rural electrification and that there is limited interest in bioenergy.

In Lao PDR there is increasing interest on the part of the government and its international partners in developing the RE sector as shown by recent and upcoming improvements to the regulatory and legislative framework. The government is currently in the process of approving the 'Renewable Energy Development Strategy' (revised in October 2011), which provides an action plan to promote RE use and production.

Viet Nam is clearly ahead of Lao PDR in terms of RE policies and regulations and liberalization of the energy sector, and has already attracted significant interest from developers and investors.

## Main constraints to bioenergy financing

Despite positive trends in both countries, the growth of the sector continues to encounter many challenges. This section outlines the main constraints that were identified during the studies. Even though the RE sector in the two countries differs in many aspects, they share the main constraints, albeit at different levels.

## Regulatory environment

All stakeholders consulted agree that a transparent and consistent regulatory environment is the most crucial factor for further bioenergy development. Because of the evolving nature of RE policies and regulations in each country, there are shortcomings in transparency, uniformity and consistency among ministries, departments and local agencies.

While both countries, in particular Viet Nam, have developed RE targets and strategies, many supporting regulations are still lacking or inadequate. The development and implementation of policies and regulations usually takes a long time, due to limited information and awareness, as well as a lack of staff working on RE and bioenergy. In addition, administrative procedures and policies may change, sometimes with little advance notice. There are also delays in obtaining licences and permits, and procedures in different provinces are not always consistent.

In the energy sector overall, there is a bias towards hydropower, large-scale power infrastructure and grid extension, putting other technologies and small-scale applications at a disadvantage. Furthermore, certain energy policies are conflicting and present an obstacle to RE development. In particular, subsidies on fossil fuels and grid electricity are still in place in both countries, which sometimes makes bioenergy more expensive. In the case of Lao PDR, it is reported that because of this, people in remote areas are reluctant to pay higher prices for RE solutions and prefer to wait for grid connection.

For Lao PDR in particular, energy development seems to focus on the construction of large hydropower plants, mainly for electricity export. Stakeholders consulted lament a lack of proactive leadership by the government to remove barriers and set a comprehensive and constructive regulatory framework for bioenergy financing. As for international investors and developers, they perceive a high political risk and an unattractive investment environment. This leads them to commonly prefer to explore opportunities in neighbouring countries such as Thailand and Viet Nam.

## Access to financing

While RE is often capital-intensive and requires long-term investment, access to long-term financing is difficult. Interest rates are considered high, as well as the requirements for guarantees and high collateral often difficult to meet for bioenergy developers with small assets and cash flow. Loan applications are reviewed mainly considering assets owned by the applicant, and project financing, where assets to be financed are treated as collateral and projected revenue as the guarantee, is still uncommon.

This situation is partly due to the unawareness of financing institutions with commercially viable technologies and business models. Banks have limited understanding of RE investment needs and their financial products are generally not tailored towards RE. They also lack the capacity to advise RE entrepreneurs about their business plans, feasibility studies, fund-raising mechanisms and the completion of loan applications.

Particularly in Viet Nam, international support programmes are in place to provide financing through local banks, but it is reported that procedures are often cumbersome and bureaucratic, leading to delays and high transaction costs to project developers.

## Low electricity tariff

For power-generating projects, project developers and financiers consider a profitable selling price a decisive factor in attracting investment from the private sector. Tariffs currently paid to RE projects are low and there are no standard formats for Power Purchase Agreements or clear subsidy systems such as feed-in tariffs to streamline and support RE project development.

**Lao PDR:** Because of the reliance on large-scale hydropower, electricity prices are low. Some large and medium hydropower power producers have been able to negotiate highly competitive feed-in tariffs, but there is no clear regulation to set feed-in tariffs, which is a constraint for developers of small hydropower schemes and other technologies. The large hydropower development sector has been able to reliably access extremely competitive financing rates and terms, with support from a range of international development project financing such as from World Bank, IFC, and KfW and this extends also to low cost of financing for the related infrastructure, including soft-loans.

**Viet Nam:** The purchase price of electricity paid by the EVN is set by the central government. At present, the maximum price is US\$0.053/kWh, too low for many projects. The government is developing a feed-in tariff scheme but it is unclear when this will be in place.

## Capacity of local entrepreneurs

Since RE is a relatively new field, most local enterprises have a limited track record and lack developing and operating experience. They often have a broad investment portfolio in which RE is only one activity among many others. The diverse portfolio helps them to reduce investment risk but investors and financiers consider this a weakness and would prefer to work with dedicated RE developers that focus on a specific technology and business model.

The experience in both countries also shows that most domestic enterprises do not have the experience to approach international investors, let alone obtain financing from them. They are reluctant to face international procedures and standards, such as background checks, need for licences and permits, and strict rules for transparency and corruption.

## Policy recommendations

Based on the stakeholder consultations and main constraints identified, the studies formulated policy recommendations to improve the environment for RE investment and financing. This section lists the main common items for both countries.

## Stronger policies and regulations

Although the governments of Lao PDR and Viet Nam have set broad orientations and targets, further deployment of RE calls for stronger support policies, to assure developers, investors and financiers of an attractive and stable environment for RE development.

Policies and targets should be supported by concrete measures. In particular, there is a need for financial instruments and incentives to support the private sector. These would include tax exemptions during the initial years of operation, import duty exemptions for RE equipment and feed-in tariffs and other subsidies. While some of these support measures are already in place, in practice information provided is not always clear and it can be cumbersome to obtain these benefits.



## Improved coordination and transparency

Limited coordination and transparency among different agencies, both at national and local levels, creates uncertainty and frustration among developers and investors. Entrepreneurs and investors have to deal with different types and levels of government agencies to obtain permits and licences. Requirements for applications and approval are not always clear and consistent, and they sometimes get stuck in bureaucratic and unclear appraisal procedures. It is recommended to streamline the coordination between different agencies, simplify and clarify procedures and to improve the information on requirements and processes.

It is also recommended to disseminate information of RE master plans and related policies from central and local governments clearly and in a timely fashion to project developers and investors to ensure transparency and facilitate their investment plans.

In the case of Lao PDR, it is recommended to set up an overall coordinating RE agency that assumes overall governmental responsibility for the sector (in line with the RE agency under the Ministry of Energy and Mines proposed in the draft Renewable Energy Development Strategy).

## Tailored financing mechanisms

To facilitate access to financing, adequate financing mechanisms should be further developed. Each country has already proposed to set up a public renewable energy fund. While developing these funds and other mechanisms, the different nature of technologies and applications should be taken into account, to allow for the broad development of bioenergy, including household-level applications and energy services in remote areas.

To increase the effectiveness of these financing mechanisms, they should be accompanied by activities to strengthen the capacity of local entrepreneurs and project developers. Particular focus should be given to business development, management, accounting and financing.



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# Challenges associated with replicating successful bioenergy projects in Thailand

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## Introduction

In rural areas of Thailand, household use of traditional forms of bioenergy such as fuelwood and charcoal is still common, despite the fact that modern energy forms such as LPG and electricity are commonly available throughout the country. The reasons for this may be that the cost of mainstream energy is considered high for many rural households and that fuelwood and charcoal are preferred fuel sources for cooking certain dishes.

Traditional forms of bioenergy are often produced and used inefficiently, using poor and outdated technologies. However, technologies are available that greatly enhance the quality and efficiency of bioenergy, and can provide several benefits to rural Thai communities including reduced cost and improved health.

In Thailand many communities make efficient and innovative use of bioenergy to produce energy. Some of these communities have had particular success with these technologies and have attracted interest from other communities who are looking for ways to replicate these successes.

Unfortunately, the stories of these 'best practice' bioenergy communities are not well publicized and not widely known to the rest of the country.



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Thus there is considerable potential for rural Thai communities to learn from these examples and broaden the choice of energy options available to them. Despite successful cases and the potential benefits to be gained, replicating successful best practice bioenergy cases presents a significant challenge.

The purpose of this study is to identify the key success factors and barriers in replicating best practices.

## Methodology

In order to identify the key success factors for community-level bioenergy projects, different community bioenergy projects were studied at two levels. First, three communities that were considered highly successful in developing bioenergy (best practice communities, BPCs) were studied in detail. Secondly, the study team investigated communities that had learned from the best practice communities and tried to replicate the bioenergy projects (replicating communities, RCs).

For the first level, the three BPCs were selected using the following criteria:

- a. The technology(s) used must have been adopted for a period of over 12 months.
- b. The community has received wide recognition for best practice in adopting bioenergy technology.

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- c. The communities selected should have diversity both in terms of location and technologies adopted.
- d. The selected communities must be self-reliant and financially viable up to a certain level.

Three communities met all these criteria, namely:

- Don Phing Dad village (Petchaburi Province, central region): high-efficiency charcoal making and biodiesel;
- Lao Khwan subdistrict (Kanchanaburi Province, western region): biogas; and
- Ta-Ong subdistrict (Surin Province, northeastern region): biogas, high-efficiency charcoal making.

Apart from the aforesaid criteria, these three communities also show a difference with regard to project development. The projects at Don Phing Dad village and Lao Khwan subdistrict were mainly developed by people in the community with limited support from external sources. In contrast, the projects at Ta-Ong subdistrict received significant external support, mainly from a local NGO and the local administrative office.

The study used two main methods. First, in-depth interviews were conducted with key stakeholders in each community, such as community leaders, villagers, government officials and local NGOs. In addition, field surveys and non-participatory observation techniques were employed to observe how the technologies are used by villagers as well as community-level management practices. After the raw data and information were collected they were synthesized and all information was classified into specific aspects such as project characteristics, technology transfer and impacts.

Following assessment of the BPCs, the RCs were identified in consultation with key stakeholders from the best practice projects. Subsequently, the RCs to be studied further were chosen using a purposive sampling method so that only communities which could provide information relevant to the study were selected.

It should be noted that the identification process for the RCs was different from that of the three BPCs. In the case of Don Phing Dad, key members provided a

**Figure 1. Map of Communities Assessed**



list of registered trainees and replicating projects they had followed up with earlier, and they also helped to make contact before giving their personal opinion. In contrast, in Lao Khwan and Ta-Ong, the management system of the learning centres is not as organized and no written information on RCs was available. Key members rarely followed up with replicating projects and could only give some names of communities from personal memory. Eventually, nine RCs for Don Phing Dad, and four each for Lao Khwan and Ta-Ong were selected.

In order to provide further insight into the elements of success and obstacles affecting the replication process, the selected RCs were divided into three groups, namely most successful, moderately successful and least successful (Table 1).



**Table 1. Criteria for success among replicating communities**

Level of success	Description
Most successful	The community has established a learning centre that has held many informal and formal training sessions for more than a year with some obvious replication successes.
Moderately successful	The community has established a learning centre and has implemented bioenergy projects successfully but there is no evidence of successful replication to other communities.
Least successful	A centre has not been established and there are only a few or no users of bioenergy technology.

## Main findings

This section provides an overview of the bioenergy projects in the three best practice and corresponding replicating communities.

### Don Phing Dad

Don Phing Dad is a farming community in Petchaburi Province in the central region of Thailand on the cusp of the southern provinces. Most villagers are not landowners and are constrained by degrading soil.

In an effort to reverse growing degradation of local soils, in 2005 the community requested the assistance of the Research and Development Institute of Silpakorn University with regard to adopting organic farming techniques. Together with the organic farming processes, the institute advocated the use of high-efficiency charcoal kilns and biodiesel production from waste cooking oil. The bioenergy operation that was subsequently adopted at Don Phing Dad involves a wide range of actors including 70 farmer households. The community now produces 1 500 litres of biodiesel and approximately 9 600 kilograms of high-efficiency charcoal per month. They also produce wood vinegar, a by-product of the charring process that is used for pest control instead of chemical pesticides.

Among the three BPCs, Don Phing Dad is considered the best example of successful implementation of a small-scale, community bioenergy project. The community has also established a training centre where people from surrounding communities can learn about the project implemented in Don Phing Dad and purchase the community's outputs of wood vinegar, biodiesel and charcoal. This centre trains more than a 1 000 people per year and has been recognized as a Ministry of Energy biodiesel learning centre and has received financial support from the Thai Government.

At the centre trainees not only learn the theory, but also how to apply this in practice in order to assure successful replication in their own communities.

The trainees subsequently created a network in their communities and link with Don Phing Dad for follow-up support.

### Replicating communities

Communities that have attempted to replicate the Don Phing Dad case are numerous and spread over Phetchaburi Province. For the purpose of the survey nine communities were studied. These communities consist mainly of rice and fruit farmers.

While most communities surveyed were supported by government funds, some relied on their own resources, especially those that witnessed firsthand the economic and health benefits of bioenergy. The production of biodiesel in the RCs was very limited due to insufficient availability of waste cooking oil feedstock. However, these communities successfully produced high-efficiency charcoal and wood vinegar. Interestingly, the least successful cases identified limited financial support from government sources and lack of waste oil as key barriers to success.

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

### Lao Khwan

Lao Khwan District is located in Kanchanaburi Province in the west of Thailand. In the past the community suffered from low agricultural productivity and lack of collaboration between local farmers. In 2007 a group

of farmers formed the Connecting Wisdom group. The group has four main activities, namely growing herbs, producing organic fertilizer, raising fish and generating biogas. The community installed a biogas digester at a cost of approximately US\$2 300 and now produces 336 cubic metres of gas per month.

In terms of generating bioenergy from biogas a key factor behind the success of the Lao Khwan case is that this subdistrict has the largest number of cattle in Kanchanaburi Province. Animal waste is the key input for the biogas plant. With the help of the Lao Khwan District Office and the Thai Health Foundation, the community in Lao Khwan established a learning centre to educate other communities about the benefits of cooperation and bioenergy. The Connecting Wisdom group subsequently expanded its network to nearby subdistricts and neighbouring provinces.

### **Replicating communities**

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

Of the four RCs studied, two communities received support from the Thai Health Foundation and two from the Lao Khwan District Office. Projects supported by the Thai Health Foundation are more organized, because staff from the foundation is working more closely with villagers. Unfortunately, only one community successfully developed the use of bioenergy in the community and established a bioenergy learning centre. Another community successfully established a learning centre but the topics are not relevant to bioenergy.

### **Ta-Ong**

Ta-Ong subdistrict has a population of 20 000, most of whom are farmers. It has the highest number of cattle in the province of Surin.

In 2007 Ta-Ong subdistrict was selected as one of 80 communities to be part of the Ministry of Energy's sustainable energy communities' programme. With the assistance of the North Eastern Thailand Development (NET) Foundation and the provincial energy office the community established biogas, high-efficiency charcoal and energy-efficient stove initiatives.

Although the community energy planning project has been completed, energy projects are still ongoing, and at present there are more than 250 high-efficiency charcoal kiln and nine biogas systems in operation, producing 24 000 kilograms of charcoal and 108 cubic metres of biogas per month. The community has received a grant from the Global Environment Facility (GEF) with the assistance of the United Nations Development Programme (UNDP) to expand the number of biogas systems in the community to 80 units.

### **Replicating communities**

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

High-efficient charcoal making has been widely adopted in nearby communities. However this has not been the case for biogas systems, mostly due to the lack of financial support. In the communities studied, biogas systems are only used at the learning centres.

## **Conclusions: conditions for successful replication**

Based on the three BPCs and their corresponding RCs, several conditions were identified that are considered crucial for the successful replication of bioenergy projects.

### **Desire to improve livelihoods**

Many farmers and rural households face a range of pressures such as degradation of the environment, high farming debt, heavy reliance on purchased chemical fertilizer, degrading soil quality, poor health, decreasing farming output, bad economic conditions and high oil prices.

All initiators of bioenergy projects, both best practice and replicating, had a strong desire to improve their livelihoods. When they learned about the benefits of bioenergy, they invested time and money in learning about technologies, experimenting and problem solving, and seeking outside assistance. Driven by different pressures they adopted bioenergy as a way to reduce their energy costs, improve their health and practise alternative ways to farming.



Where such pressures were not considered particularly strong, communities lacked sustained interest in maintaining their bioenergy projects. Therefore, while villagers may have a certain interest in learning about these technologies, a stressful environment can be considered a necessary condition for the project to be successful in the long run.

### Availability of external support

This condition covers several levels of support. First, villagers need to be motivated by examples of success and benefits to be gained from the bioenergy technologies. These can come from public media, a facilitator or even word of mouth. Under stressful conditions, farmers who are shown the benefit of alternative approaches will be keen to implement them.

Second, communities often lack the technical expertise to build bioenergy systems and to properly operate and maintain them; the study showed that external support is crucial in this regard. As shown by the case studies, this can come from a variety of sources, such as local administrative offices, NGOs or nearby universities.

Finally, while some villagers are able to implement projects using their own resources, most require additional financial support, because many have debts or high farming expenses. Apart from project implementation, financial support is also used to cover training (including travel and accommodation), as well as compensation for lost opportunities to generate income.

### Economic benefit

In all of the projects people wanted to lower their energy costs in farming or household use. Even though most projects were developed for self-reliance purposes and not for commercial reasons, many villagers mentioned that 'go' or 'no-go' decisions were based on a monetary cost-benefit analysis.

In a few cases where people already had invested in a bioenergy project, they doubted whether they could gain sufficient benefits, and they hesitated to continue. For example, in the case of biodiesel, the higher the difference in price for oil and biodiesel, the stronger the motivation was to produce biodiesel, while the production would be low or even halted whenever the diesel price was low. This shows that economic benefit is a necessary condition for a long-term operation.

### Adequate supply of feedstock

For all technologies the quantity and quality of the feedstock material significantly affects the success of a bioenergy project. For instance, biogas systems were widely and successfully adopted in Lao Khwan and Ta-Ong because of the large number of cattle, whereas in Don Phing Dad cattle raising is uncommon so biogas is not used. In the case of biodiesel from used cooking oil, several producers face supply problem because of multiple buyers and competing uses, causing production to be limited and intermittent.

This shows that a proper study of available feedstock and its continuous availability is crucial for the long-term success of a project and indiscriminate promotion of bioenergy technologies without looking into locally available materials should be avoided.

### Local champions and management

Every community that successfully implemented a bioenergy project had a key person or a group of people who took the lead in organizing the community to develop bioenergy activities. Apart from enthusiastic key people within the community, any successful project also sources outside experts who support the community in terms of technology and management.

While key people are crucial, a structured management system plays an important role, particularly for the ability to replicate projects. All best practice communities and some of the most successful ones have a structured management system where each group committee has a clear role and responsibility. In contrast, some of the successful RCs have determined leaders, unfortunately without a clear management system, and they are not successful in expanding bioenergy activities throughout their community as much as they originally anticipated.

## Policy recommendations

### Promotion of rural bioenergy solutions

Bioenergy promotion will raise awareness among communities of its use and benefits, showing ways to use local resources to reduce their expenses and improve their livelihoods. This can be done at several levels, starting with public media such as national television and newspapers.

Information should also be made available to relevant government agencies, in particular local units such as district offices, to allow them to support communities under their jurisdiction. The same applies to existing training centres, educational institutions and rural networks, so they can further promote bioenergy locally. Additionally, mobile demonstration units that travel to communities could be used to expose communities directly to bioenergy and provide on-the-ground learning.

The study found in particular that local learning centres and networks play an important role in developing bioenergy and many successful project developers have used them to overcome obstacles in implementing their projects. Therefore the government should strive to strengthen the capacity of learning centres related to rural development, organic farming and bioenergy, in terms of funding, management and technology. Subsequently, they can be instrumental in supporting community management systems, helping villagers to conduct financial management, strategy development and implementation.

### Coordinated and sustained support by government agencies

Many different government agencies are providing support to communities, both in terms of funding and technical assistance. These include district offices, the Department of Alternative Energy Development and Efficiency (DEDE), the Thai Health Promotion Foundation and the Ministry of Agriculture and Cooperatives.

While such support is essential, it is not always effective. Villagers mention that activities conducted by different agencies often cause confusion and create a certain degree of redundancy, resulting from a lack of coordination among government agencies. In addition, government support is often intermittent and sometimes seems to be related to political activities, creating distrust of government officials among villagers.

Therefore, there is a need for better coordination and planning of community bioenergy activities, possibly under a central coordinating body. In this regard there has been a recommendation to establish a National Alternative Energy Office (NAEO), with provincial branches, as the host to drive all bioenergy and other alternative energy activities at national and local levels. The NAEO could be developed from the alternative energy task group that already exists within DEDE.



# Potential for social indicators to guide bioenergy policies

Sittha Sukkasi<sup>1</sup>

## Introduction

Bioenergy is essentially a form of development, a technological pathway that can help people leverage their natural resources and lead them to a better quality of life. Like other forms of development, bioenergy development may or may not be sustainable, and its sustainability can be assessed by economic, institutional, social and environmental aspects. Sustainability assessment is especially critical for development that is based on currently evolving technologies. While such technologies have potential to bring people a better standard of living, they may also have unforeseeable and negative side effects, which can undermine the sustainability of the development itself. Indicators are key tools for planning and monitoring the sustainability of development. There are many sustainability indicators including the *Triple Bottom Line*, the *UN's Indicators of Sustainable Development*, the *Dashboard of Sustainability* and the *Human Development Index*.



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However, these indicators are unsuitable for small-scale and context-specific applications. The present work proposes a way to formulate indicators that are tailored to bioenergy development in specific settings. The method involves interaction with the stakeholders to identify the dimensions of the development, to analyse the issues associated with each dimension and to choose indicators that can quantitatively measure the development's impact with respect to each issue. While there are many well-known economic and environmental indicators that are readily applicable to small-scale and context-specific development, those in the social aspect are harder to define. This paper focuses on the formulation of social indicators. Biodiesel development in the Greater Mekong Subregion is used as a case study.

## Development as a pathway

The concept of sustainable development has been given many different descriptions. The most well known was given by Gro Harlem Brundtland, the chair of the World Commission on Environment and Development (Brundtland 1987):

*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

There are two key concepts embedded in Brundtland's description. First, there is the concept of *needs*. People have needs, and they can be fulfilled by development. Second, there is the concept of *limitation of resources*. Development requires

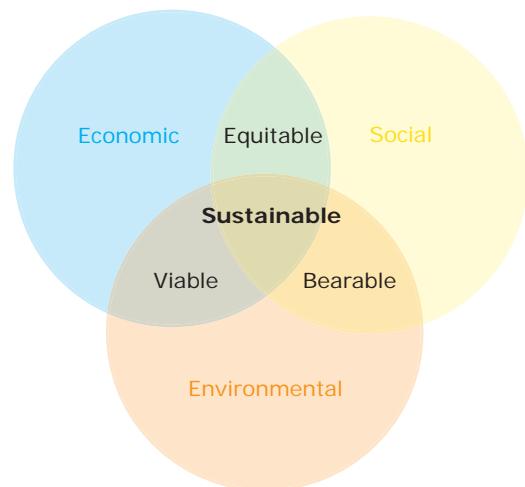
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resources, which are finite, and one generation's overexploitation of resources might jeopardize the availability of these resources to future generations.

Other descriptions similarly revolve around these key concepts. For example, *Caring for the earth: a strategy for sustainable living* (IUCN *al.* 1991)). Additionally, many descriptions also specify the key economic, environmental and social aspects for sustainable development as depicted in Figure 1.

Development can also be viewed as a pathway that can help people leverage their natural resources

**Figure 1. Key aspects of sustainable development**



Source: Consultative Group on Sustainable Development Indicators. 2002

and lead them to a better state (Figure 2). There are many technological means, or pathways, that can potentially lead people to the same developmental goal. Nonetheless, some pathways may be convoluted, and some may create problems as side effects. Many pathways also involve technologies that are still

evolving and whose directions and side impacts are still unclear. Sustainable developmental pathways can lead people to developed states without causing economic, social and environmental problems.

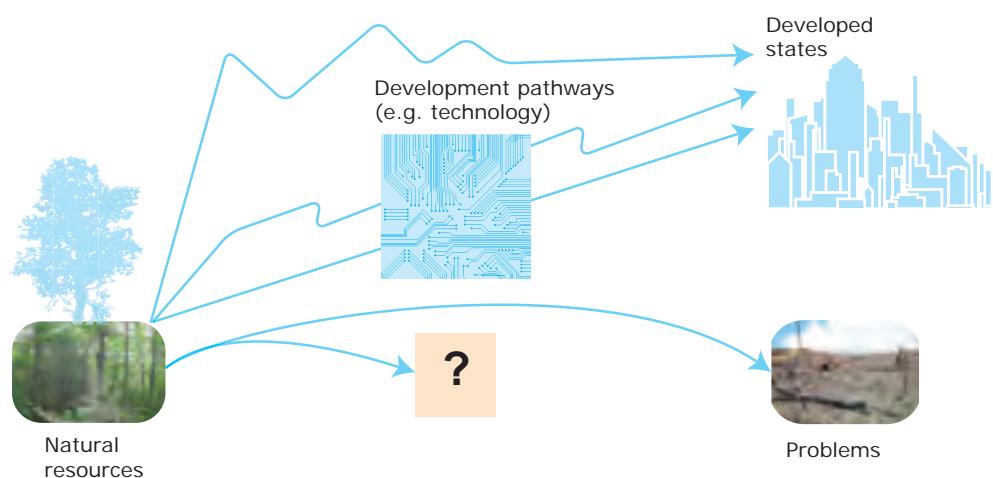
In this regard, bioenergy could be considered as a set of developmental pathways. Each bioenergy technology can help people utilize biological resources and lead them to a state of optimized energy needs. Some bioenergy technologies are more straightforward than others, and some could easily create negative side impacts without proper planning and management. There are also many fledgling bioenergy technologies whose impacts are still equivocal.

## Sustainability indicators

Sustainability indicators can provide information on the state of specific aspects of the development. In other words, they can help people gauge whether a pathway is leading them towards the goal and whether they are headed in a sustainable direction.

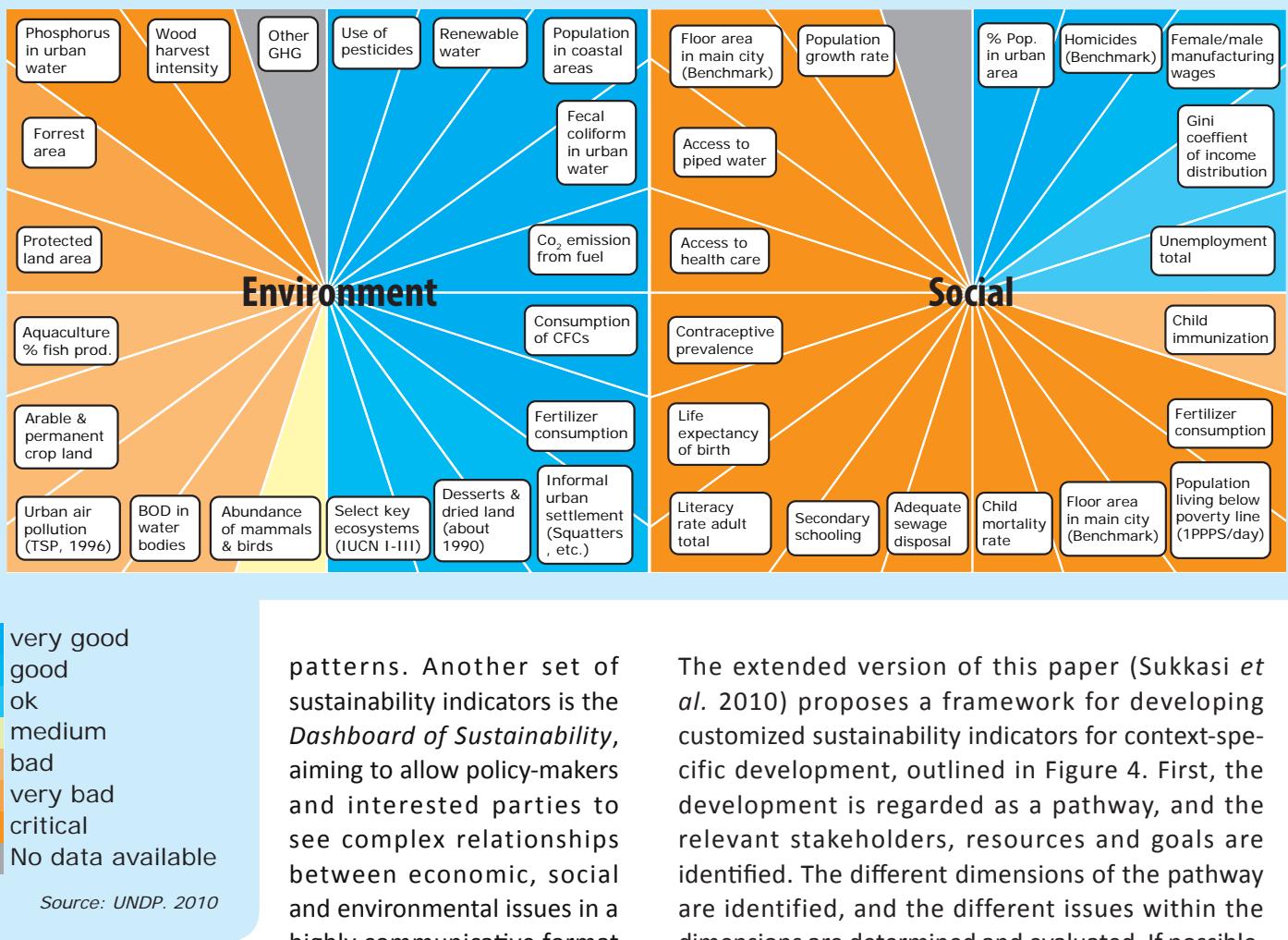
There are many sustainability indicators. John Elkington proposed the concept of *Triple Bottom Line* (Elkington 1998), suggesting that companies need to evaluate their performances not only in terms of profit, but also with respect to their impacts on people and the planet. The Commission on Sustainable Development (CSD) developed *Indicators of Sustainable Development* to help countries measure their progress on achieving sustainable development at the national and international levels (United Nations 2007). There are 96 indicators in the themes of poverty, governance, health, education, demographics, natural hazards, economics, atmosphere, land, oceans, seas and coasts, freshwater, biodiversity development, global economic partnership, and consumption and production

**Figure 2. Developmental pathways**



Source: Sittha Sukkasi

Figure 3. The Dashboard of Sustainability



(Consultative Group on Sustainable Development Indicators *et al.* 2002). Examples of the social and environmental aspects of the Dashboard are shown in Figure 3. Another measurement commonly used to gauge the social aspect of sustainable development is the *Human Development Index*. It is derived from four indicators in the areas of health, education and living standards (UNDP 2010).

While the aforementioned indicators are suitable for measuring the progress of development on a large scale, they are not practical for development in very specific contexts.

## Customized sustainability indicators for context-specific development

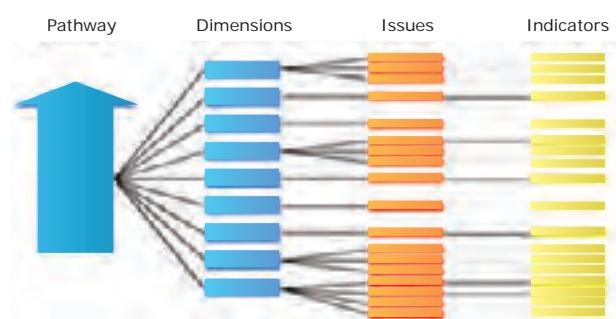
For development in a very specific context, such as bioenergy development in a particular region, sustainability indicators could be customized to measure more meaningful, context-appropriate states of the development. The customized indicators could be more useful than generic indicators for guiding related policies and monitoring development.

patterns. Another set of sustainability indicators is the *Dashboard of Sustainability*, aiming to allow policy-makers and interested parties to see complex relationships between economic, social and environmental issues in a highly communicative format

The extended version of this paper (Sukkasi *et al.* 2010) proposes a framework for developing customized sustainability indicators for context-specific development, outlined in Figure 4. First, the development is regarded as a pathway, and the relevant stakeholders, resources and goals are identified. The different dimensions of the pathway are identified, and the different issues within the dimensions are determined and evaluated. If possible, the analysis of the dimensions and issues should involve the stakeholders. Related indicators are then proposed for each issue, in order to quantitatively measure the development's impact with respect to the issue.

While there are many well-known economic and environmental indicators that are readily applicable to small-scale and context-specific development, those in the social aspect are harder to define.

Figure 4. Framework for developing customized sustainability indicators for context-specific development



Source: Sittha Sukkasi

## Social sustainability indicators for biodiesel development in the Greater Mekong Subregion

The dimensions and related issues of biodiesel development in the Greater Mekong Subregion (GMS) have been analysed (Sukkasi *et al.* 2010). The process involved site visits and interviews with stakeholders consisting of local energy companies, investors, international banks, environmental organizations, development agencies, research institutes, universities and local governmental offices of industry, energy, forestry, environment, agriculture, transportation, commerce, rural development and policy. The identified dimensions of the pathway were policies, governance and management, infrastructure, technology and feedstock, impacts on the poor and rural livelihood, and climate change and the environment. Within these dimensions, 19 key issues were identified and analysed.

Building upon these issues, the extended version of this paper proposes sustainability indicators for GMS biodiesel development. With regard to the harder-to-define indicators in the social aspect, the following are proposed:

### Technology and feedstock

- The percentage of population whose access to and capability to afford food is negatively affected by the chosen feedstock crops (related to the issue of feedstock choice and competition with food production).
- The percentage of unproductive land utilized for activities related to the chosen feedstock crops (related to the issue of feedstock choice and productive land).
- The income generated from secondary uses of the chosen biofuel feedstock crops (related to the issue of potentials to generate additional revenue streams from biofuel feedstock crops).
- The percentage of population who work on producing or maintaining the chosen biofuel technologies locally (related to the issue of locally appropriate technologies).

### Impacts on the poor and rural livelihoods

- The percentage increase in income from planting biofuel crops on marginal land (related to the issue of enhanced rural incomes at individual and community levels from small-scale biofuel operations).
- The proportion of biofuel-related jobs (also related to the issue of enhanced rural incomes at individual and community levels from small-scale biofuel operations).
- The number of different kinds of feedstock crops (related to the risk that all farmers in one area will follow short-term price increases and rush to grow the same crops).

Many indicators can also be proposed in this dimension to gauge the issue of exploitation of land concession schemes:

- The percentage of agricultural land that is affected by biofuel land concession.
- The percentage of landownership that is lost due to biofuel land concession.
- The percentage of population whose access to water resources is affected by biofuel land concession.
- The percentage of population whose access to roads is affected by biofuel land concession.
- The percentage of population whose income is affected by biofuel land concession.
- The percentage of population that is displaced by biofuel land concession.

### Conclusions

A framework for developing customized sustainability indicators for context-specific development is proposed. By systematically analysing the dimensions and related issues of a developmental pathway, indicators for measuring specific issues pertaining to the sustainability of the development can be formulated. These customized indicators can facilitate quantitative assessment in a more meaningful way than generic sustainability indicators.





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# Using microfinance for farm/household-level bioenergy technologies

Riaz Khan<sup>1</sup>

## Introduction

If we look at the Earth City Lights layer in Google Earth® we see a very uneven distribution of electric lights across the South Asia and Southeast Asia regions (Plate 1).

There are vast areas which are known to be populated but have limited access to electricity. The cities are well lit, yet many rural areas are completely dark. This lack of access is due to the lack of capacity of the national and sub-national grids.



Plate 1. South and South East Asia Earth City Lights

Source: Google Earth

## Lack of access

Approximately 41 percent of the population of Bangladesh did not have access to electricity from the grid in 2009 (International Energy Agency, 2012). This translated into 95.7 million people without access to electricity. The situation is even worse when we look at the urban-rural divide. In Bangladesh in 2008, while 76 percent of urban dwellers had access to electricity, only 28 percent of the rural population had similar access (International Energy Agency, n.d.).

Neither the public sector nor the private sector has been able to provide comprehensive power supply. Solutions to this problem have started to emerge from social enterprises relying on off-grid technologies.

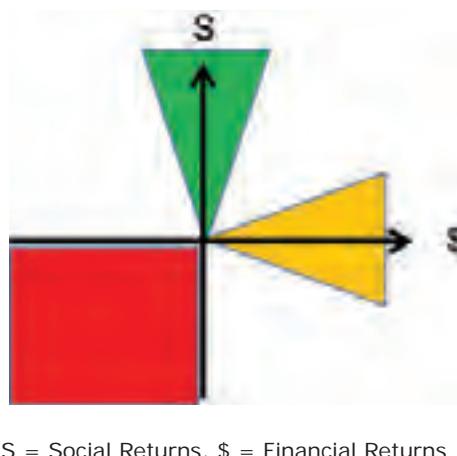
## Social business

In order to solve social problems we need to look at organizations that combine the idealism of the grassroots sector with the efficiency of the business sector. People are therefore increasingly looking to social enterprises and social businesses to solve social problems. But what do we mean by these terms?

In order to better understand this context, it is useful to visualize organizations functioning in a space where we measure not only financial returns but also social returns. In Figure 1 the horizontal line measures financial returns whereas the vertical line measures social returns.

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Figure 1. Social and financial returns in the corporate context



S = Social Returns, \$ = Financial Returns

We divide organizations into two broad categories: conventional companies and non-profit institutions. Most conventional companies are concerned with increasing their earnings and profits. As they provide a service, there is a social component to their work, but they aim to provide maximum value to their shareholders, in the form of profits. Therefore, when we think of such companies we think of their performance primarily in terms of their financial returns. In Figure 1 the horizontal axis represents the financial performance of a company. Most profit-making companies would be working within the yellow triangle that lies along the horizontal axis. If a company is operating in the upper half of the triangle then the company is making a profit and contributes positively to society. However, if there is a conflict between social goals and financial goals the financial goals will usually trump the social goals.

On the other hand, non-profit, charitable and social enterprises work along the vertical axis that represents social goals. They aim to work within the green triangle that lies along the vertical axis in Figure 1. Charities for instance do not usually make money from the services that they offer, but are dependent on donations to fund their operations. Social enterprises are also operating within the green triangle that lies along the vertical axis. Once again the main goal of these organizations is to do social good and they look for money from grants and donations. If a social enterprise is able to provide a service for which it can charge, then it may be able to cover its cost of operations. This will make the initiative economically viable. In that case the enterprise will be in the happy position of financial sustainability and positive social returns. Naturally all enterprises want to stay out of the red zone where they are neither profitable nor are they doing any social good.

Social businesses are entities that aim to function within the right half of the green triangle. We will briefly discuss the concept of social business as defined by Nobel laureate Professor Muhammad Yunus. There are two types of social businesses. Type I is defined as a non-loss, non-dividend company dedicated to a social cause. Non-loss means that the company covers its cost of operations and can even make a profit. Non-dividend means that the investors cannot take any profit out of the company. They can only take back their original amount of investment. After that any further profit must be put back into the company. The investors cannot even adjust their investment for inflation. Finally the company must be dedicated to solving a social problem. The most publicized example of this is the Grameen Danone joint venture in Bangladesh that is dedicated to supplying yoghurt fortified with vitamins and minerals to combat malnutrition among poor children (Yunus & Weber, 2010).

The other type of social business or a Type II social business is a business that is profit making, owned by the poor and dedicated to solving a social problem. The best known example is the Grameen Bank that has been providing credit and savings for the poor for over 30 years.

## Application to renewable energy technology

Grameen Shakti is a non-profit organization that is part of the Grameen family of organizations. The company works using the network that has been built up by the Grameen Bank and provides a variety of renewable technology solutions to poor households. In particular, the company sets up loans for its customers so that they can buy the systems on a staggered payment system.

The major energy requirements of poor households are for lighting and cooking. Lighting is being tackled through solar energy and cooking through biogas and energy efficient stoves. Grameen Shakti installs solar home systems, biogas plants and improved cook stoves. Solar household systems are the largest and oldest of the services. Solar home systems are provided in a variety of packages. Rural solar home systems range from US\$120 to US\$900. The capacity of these systems vary from lighting one compact fluorescent lamp (CFL) to systems that can power two 20 watt lights, two fans and a 21" colour TV. In urban areas, Grameen Shakti provides even larger systems with the most expensive system costing over US\$2,000. This system can power two CFLs (20 watts), two ceiling fans, a 21" colour TV and a computer for four hours.

The range of systems means that customers have a large choice in what they can buy. Grameen Shakti has built up a large country-wide logistical network that allows it to provide services to rural and urban households. It has a good after sales service to ensure that once the solar home system is installed it can handle any after sales issues. It has worked on bringing down the cost of the technology and has trained people in rural areas at its Grameen Shakti technology centres.

In addition, Grameen Shakti provides its customers with financing options so that they can pay for their loans through monthly installments. Table 1 shows the payment options that are available to customers.

Table 1. Financing options for solar home systems

Mode of repayment	Down payment	Installment	Service charge (flat rate)
Option 1	25%	24 months	6%
Option 2	15%	36 months	8%
Option 3	100% cash payment with 4% discount.		

Source: Grameen Shakti ([www.gshakti.org](http://www.gshakti.org))

Plate 2. Installing a solar panel



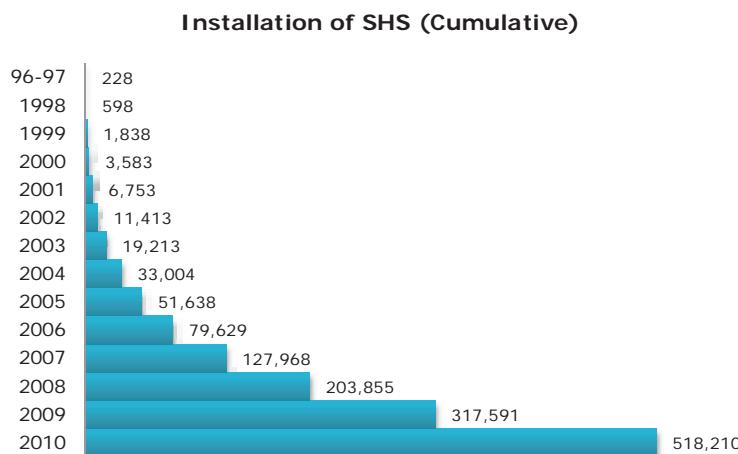
Plate 3. A Grameen Shakti technician training centre



Women are trained at the various Grameen Shakti technology centres and are then employed as technicians to help in after sales service. By 2010 Grameen Shakti had installed over 0.5 million solar home systems in the country. Figure 2 shows the exponential growth of installations of solar home systems by Grameen Shakti.

Besides solar home systems Grameen Shakti is also involved in building small household-level biogas plants and installing improved cooking stoves in villages. Although these programmes are relatively new compared to the solar energy programme, Figures 3 and 4 show that they have enjoyed robust growth over the last few years.

**Figure 2. Total number of solar home system installations**

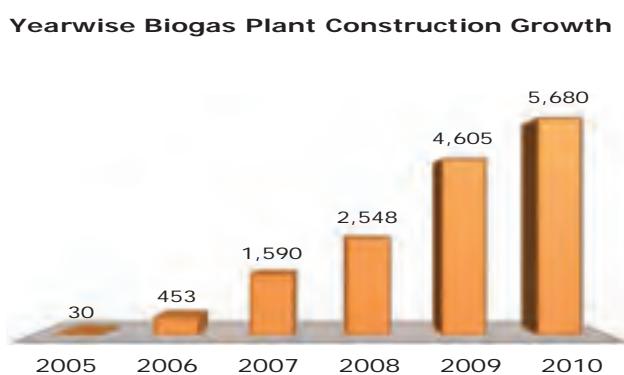


Source: [www.gshakti.org](http://www.gshakti.org)

## Conclusion

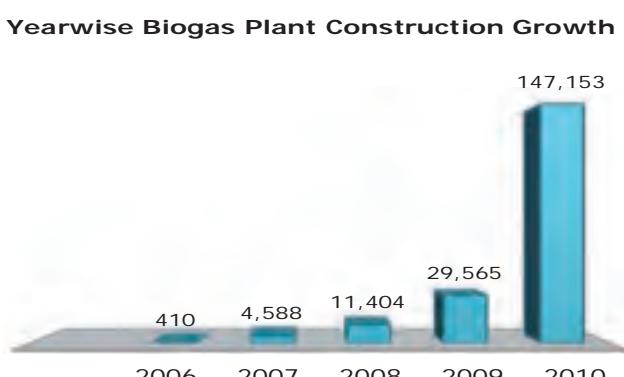
This paper argues that supply of clean energy is too important a matter to be left alone to conventional, profit-seeking companies. There is a need to widen our thinking to include social parameters of returns, in addition to the purely financial ones, and non-profit organizations can play an important role in this respect. Over recent years in Bangladesh there have been many schemes for microfinance credits tied to installment and use of small-scale renewable energy devices. So far these arrangements seem to provide benefits to household-level consumers at an affordable price, where traditional market forces would not have been interested in providing funding.

**Figure 3. Grameen Shakti biogas plant construction**



Source: [www.gshakti.org](http://www.gshakti.org)

**Figure 4. Grameen Shakti improved cook stoves**



Source: [www.gshakti.org](http://www.gshakti.org)

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## *SECTION IV:* *CLIMATE FRIENDLY BIOENERGY*

**FOOD, FUEL AND CLIMATE CHANGE: POLICY PERFORMANCE  
AND PROSPECTS FOR BIOFUELS IN THAILAND**

*SHABBIR H. GHEEWALA*

**LINKING ENERGY, BIOSLURRY AND COMPOSTING**  
*M. FOKHRUL ISLAM*

**BIOCHAR POTENTIAL FOR ASIA AND THE PACIFIC**  
*YOSHIYUKI SHINOGI*

# Food, fuel and climate change: policy performance and prospects for biofuels in Thailand

Shabbir H. Gheewala<sup>1</sup>

## Overview

Biofuels have been strongly promoted in Thailand over the past few years and they also form a part of the long-term strategy to increase the use of alternative sources of energy. As the feedstocks for biofuels are agricultural products, they could compete with food unless adequate precautions are taken. The apparent greenhouse gas (GHG) benefits of substituting fossil fuels with biomass-based fuels could also be negated if there are large-scale conversions of land, especially tropical rainforests. This paper looks at the biofuels policy in Thailand and analyses its implication to food security and climate change inducing GHGs. Conditions are proposed under which the biofuel policy in Thailand could be adequately met without compromising food supply as well as reducing GHG emissions.



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## Introduction

Thailand has been promoting the use of agriculture-based liquid transportation fuels, referred to as biofuels in this paper, for several years. They comprise ethanol or gasohol (a blend of ethanol with gasoline) and biodiesel. One of the major reasons for the promotion of biofuels is that they are based on feedstocks that are available in Thailand – bioethanol is mainly being produced from sugar-cane molasses and cassava, and biodiesel from palm oil. This leads to a decrease in the importation of crude oil which is the main source of fossil-based liquid transportation fuels, resulting in a saving of foreign exchange as well as contributing to an increase in energy security (Silalertruksa and Gheewala 2010; Bell et al. 2011). It is also anticipated that the use of local feedstocks will provide benefits to the rural economy by stabilizing the prices of certain agricultural produce. Biofuels are also anticipated to help in mitigating climate change as they may release fewer greenhouse gases (GHGs) than their fossil energy counterparts (Nguyen et al. 2007a,b; Pleanjai et al. 2009a,b).

The last point was almost taken for granted initially when biofuels were assumed to be 'carbon neutral'; the carbon dioxide released from the combustion of biofuels is equivalent to that taken up from the atmosphere by the plants used as feedstocks, during photosynthesis. This idea was quickly seen to be inaccurate when the whole life cycle of the biofuel was considered. Thus, GHG emissions

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from feedstock cultivation (particularly from the manufacture and application of nitrogen fertilizers), feedstock processing and transportation between the various life cycle phases are outside the scope of carbon neutrality, which is limited to plant growth and biofuel combustion only. More recently, it was observed that change of land use, especially from forests and other areas of high carbon stocks, to agriculture results in the release of a huge amount of GHGs which could far outweigh the GHG benefits compared to fossil fuels (Danielsen et al. 2008; Fargione et al. 2008).

This is an issue that needs to be considered in any evaluation of the GHG implications of biofuels. Further still, concerns have been raised on indirect land-use change, which refers to the change in use of land as a consequence of direct land-use change elsewhere.

Change in the use of land from cultivation of food to feedstocks for biofuels causes competition with food if food crops are directly diverted for production of biofuels (Daniel et al. 2010). Competition is not limited only to land but also to another limited resource – freshwater (Gheewala et al. 2011a).

This paper examines the biofuel policy in Thailand with respect to feedstock security and GHG emissions when the policy targets are to be met. The results are based on studies carried out over several years under the Life Cycle Sustainability Assessment Laboratory at the Joint Graduate School of Energy and Environment in Bangkok.

## Biofuel policy in Thailand

There is a strong policy drive in Thailand for the increase of renewables in the energy mix, particularly the use of biomass. The most recent 15-year alternative energy development plan from the Ministry of Energy lays particular emphasis on the promotion of biomass (DEDE 2009). In the short term (2008-2011), it focuses on promotion of biofuels, heat and power generation from biomass and biogas as the major alternative energy sources. In the medium term (2012-2016), it focuses on developing new technologies for alternative energy, including biofuel production. In the long term (2017-2022), it proposes to make Thailand a hub of biofuel export in the Association of Southeast Asia Nations (ASEAN) region. The plan includes a target of 20.4 percent alternative energy in the final national energy mix by 2022, biomass for heat, power and transportation fuels playing a key role.

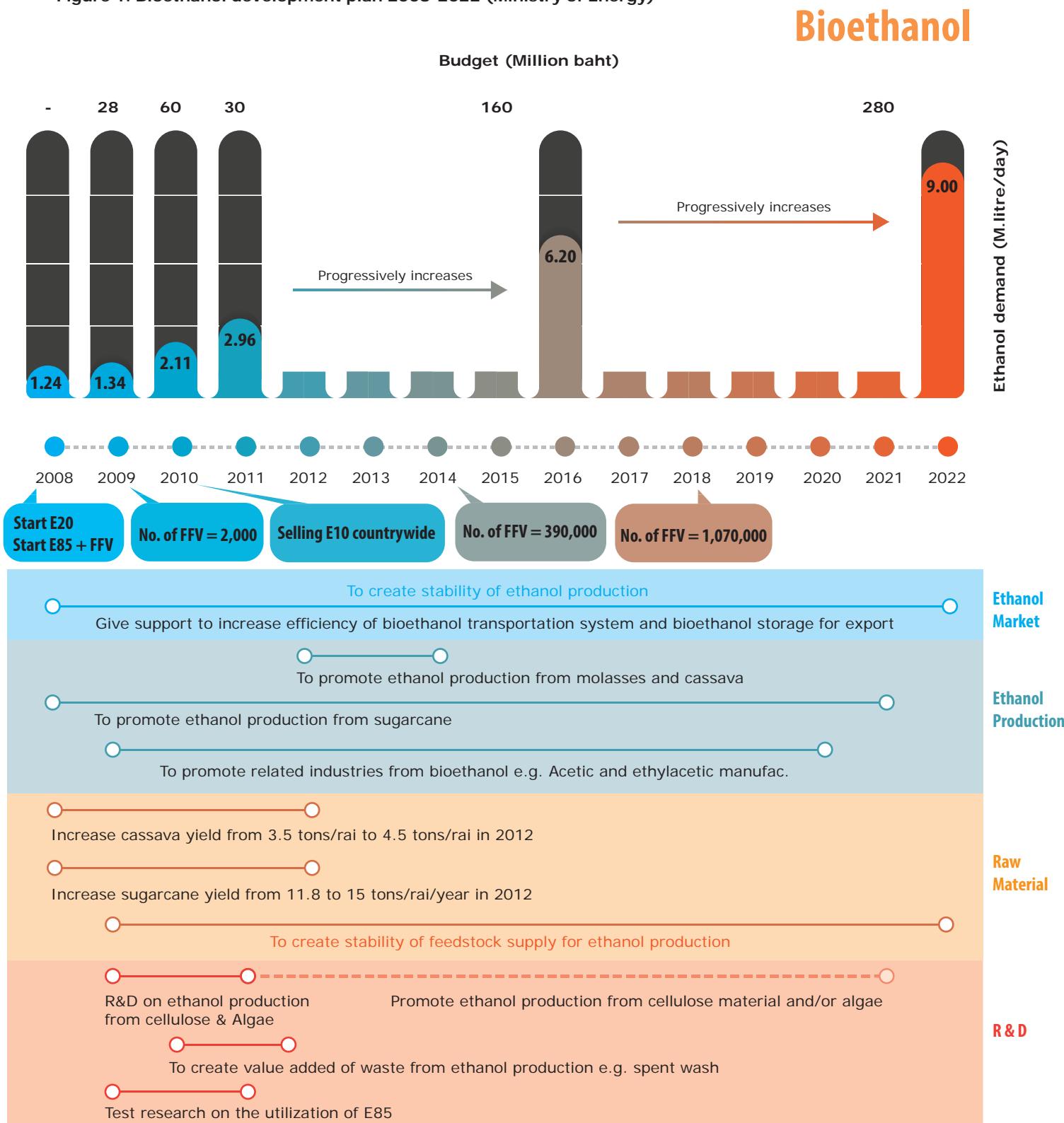
## Bioethanol development plan

According to the Ministry of Energy, bioethanol production targets for 2011, 2016 and 2022 were 2.96, 6.2 and 9.0 million litres/day, respectively (Figure 1) (DEDE 2009). Ethanol is currently being produced from sugar-cane molasses and cassava. Ethanol production directly from sugar-cane juice is also planned for the future. Sugar cane and cassava are both well-established agricultural products and important for the domestic market as well as export. The increasing demands on sugar cane and molasses for ethanol are to be met by increasing the yields of sugar cane and cassava as indicated in Figure 1. Research is also planned for production of ethanol from cellulosic materials (particularly agricultural residues) as well as algae. A 10 percent blend of ethanol with gasoline, E10, has been available for several years since 2005 and has well-established usage; prices of E10 are maintained lower than gasoline through government incentives to encourage its use. Since 2008, E20 (a 20 percent blend of ethanol with gasoline) has been available once again with government incentives to maintain an attractive price. Many automobile companies are producing vehicles which can use E20. E85 (an 85 percent blend of ethanol with gasoline) has also been introduced since late 2008 on a very limited scale although vehicles that can use this blend are not readily available in Thailand.

## Biodiesel development plan

The 15-year alternative energy plan from the Ministry of Energy has proposed targets of 3.02, 3.64 and 4.50 ML/d biodiesel for the years 2011, 2016 and 2022 respectively [11]. This plan has been adjusted from a previous target of 9 ML/d biodiesel in 2022. The biodiesel is mainly produced from palm oil and stearin, both products of oil palm. Palm oil is widely used for cooking, thus care must be taken to avoid the food versus fuel conflict. The government has proposed an improvement in yield of oil palm trees and also an additional plantation of 2.5 million rai (0.4 million ha) to meet the increasing demand (Figure 2). Jatropha is another plant which can be used as a feedstock for biodiesel production; it has been under research for several years and community scale applications are anticipated. Biomass-to-liquid (BTL) and algal biodiesel are also planned on a longer term. Pure diesel has been entirely phased out of the market and currently the fuel being sold as diesel is actually B3 (3% blend of biodiesel with diesel); B5 (5% blend of biodiesel with diesel) is planned by the end of 2011. B5 is also already available in the market as an option.

Figure 1. Bioethanol development plan 2008-2022 (Ministry of Energy)



## Biofuels performance and prospects

Several energy balance and life cycle assessment (LCA) studies, particularly dealing with life cycle GHG emissions have been performed on biofuels from various feedstocks in Thailand. Bioethanol from sugarcane molasses and cassava and biodiesel from palm oil, used cooking oil and jatropha have been studied (Nguyen et al. 2007a,b,c; Nguyen and Gheewala 2008a,b,c; Pleanjai et al. 2009, a,b;

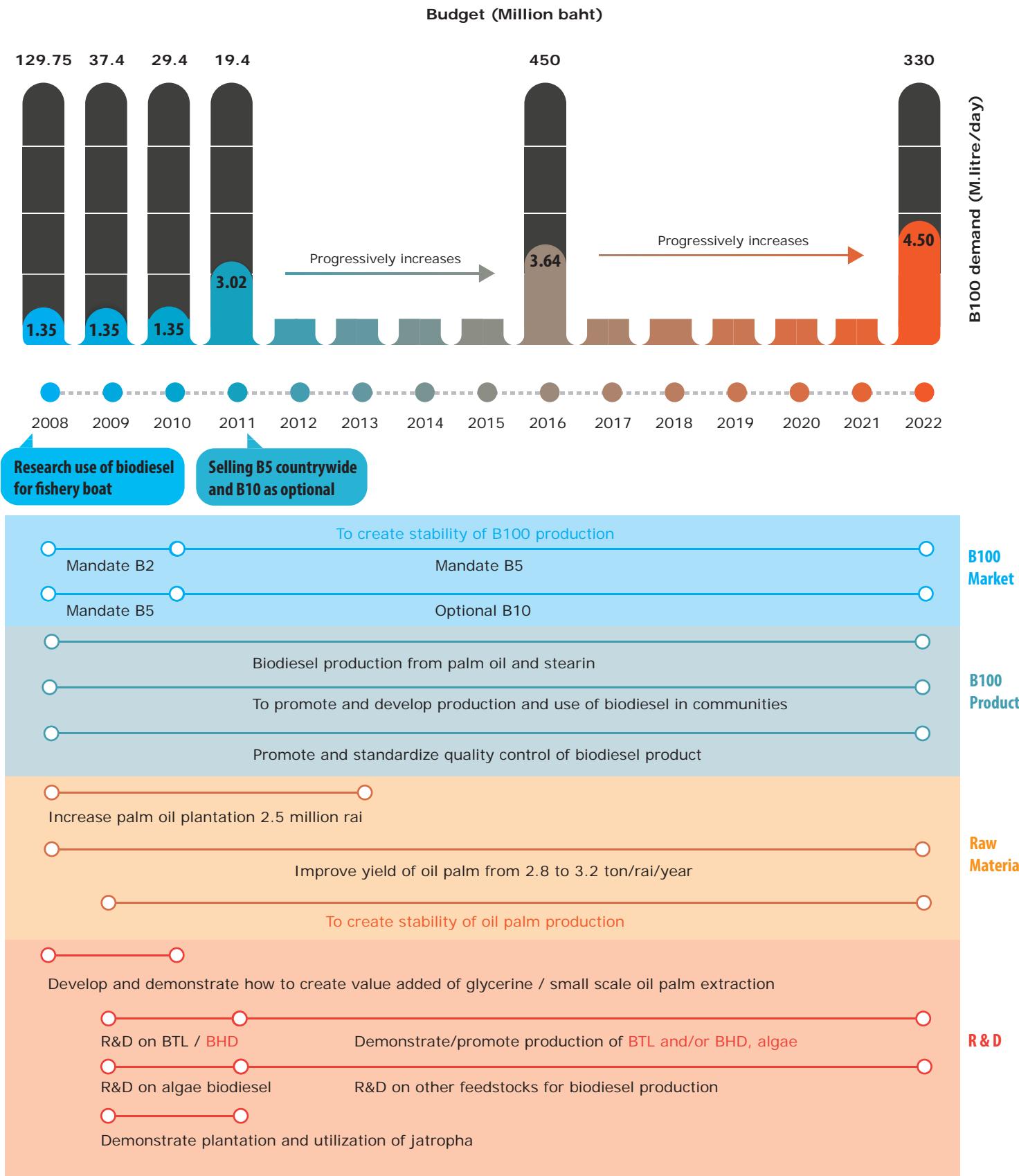
Prueksakorn and Gheewala 2008; Prueksakorn et al. 2010). The studies were conducted over several years with changing conditions. The findings from the most recent studies are discussed in this paper.

## Performance and prospects of bioethanol

A summary of the results from the various studies on bioethanol from various feedstocks is provided in Table 1 below (Silalertruksa and Gheewala 2010). The

Figure 2. Biodiesel development plan 2008-2022 (Ministry of Energy)

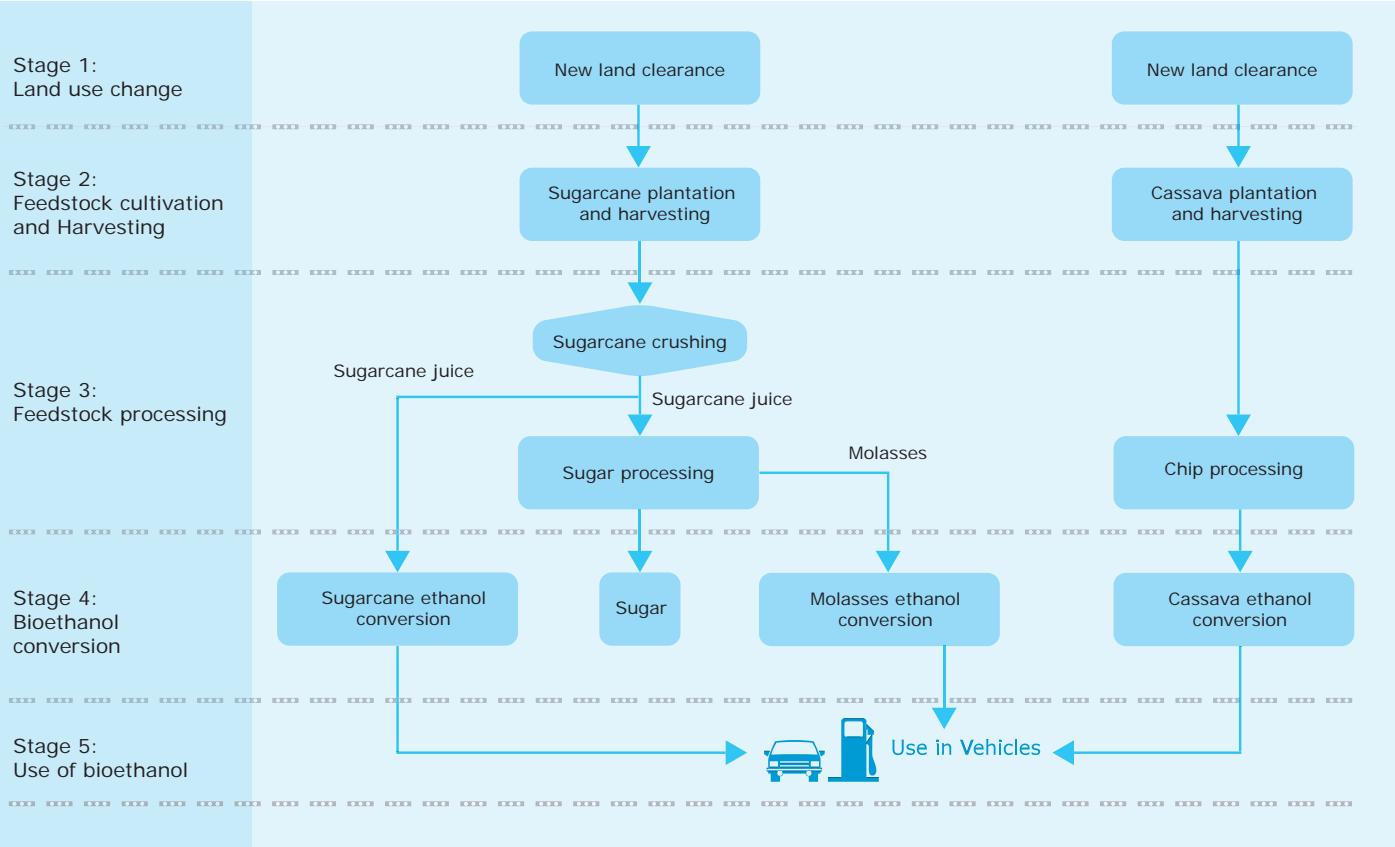
# Biodiesel



system boundaries of the various chains are shown in Figure 3. It must be noted that these results are drawn based on the assumption of status quo vis-à-vis land use change as bioethanol production relies mainly on surplus feedstocks from the existing plantation areas.

Also, both sugarcane and cassava are being planted traditionally in the same area for many decades; thus, there is no recent conversion of land. So Stage 1 in Figure 3 is not included for the results presented in Table 1.

**Figure 3. Life cycle stages of palm biodiesel**



As none of the ethanol plants are using sugar-cane juice directly for ethanol production (only sugar-cane molasses), the values for that feedstock are from Brazil. A range of results has been obtained due to the various operating conditions and energy carriers in the different plants as explained in the footnotes of Table 1.

- a. Average GHG emissions of three molasses ethanol plants, Allocation factor (AF) of sugar: molasses = 4:1.
- b. A molasses ethanol plant which used bagasse as fuel.
- c. A molasses ethanol plant which used coal as fuel; AF of sugar:molasses = 8.6:1.
- d. Ethanol produced from dried cassava chips in Thailand; ranges of GHG emisission were reviewed from various studies (Nguyen et al. 2009a; Silalertruka and Gheewala 2009; Hue et al. 2004).
- e. Cassava ethanol plant that used biomass as fuel.
- f. Cassava ethanol plant that used coal as fuel.
- g. Sugar cane in Brazil (sugar-cane juice) (Macedo et al. 2008).
- h. Estimations based on energy content of ethanol = 21.2 MJ/L; energy content of gasoline = 32.4 MJ/L.

Thus, a litre of ethanol will produce the same performance as 0.65 L of gasoline. Gasoline fuel-cycle GHG emissions = 2.9 kg CO<sub>2</sub>eq./L gasoline.

Source: Silalertruka and Gheewala (2010)

**Table 1. Life cycle GHG performance of bioethanol from various feedstocks**

Feedstock	Estimated GHG emissions (kg CO <sub>2</sub> eq/L biofuel)		Net avoided GHG emissions compared to gasoline <sup>h</sup>	
	Baseline	Range	Baseline	Range
Molasses	0.68 <sup>a</sup>	0.65 <sup>b</sup> -3.46 <sup>c</sup>	64%	66%--(-82%)
Cassava/dried chips	0.96 <sup>d</sup>	0.77 <sup>e</sup> -1.92 <sup>f</sup>	49%	59%--(-1%)
Sugar-cane juice	0.5	0.26 <sup>g</sup> -0.5	72%	82% <sup>c</sup> -76%

The implications of the policy targets on feedstocks are presented in Table 2 (Silalertruksa and Gheewala 2010). Three scenarios are defined considering varying yield improvements. The low yield improvement scenario is the business-as-usual where yields are projected to increase as shown by the historical data as if there is no policy promoting biofuel development. In the moderate yield improvement scenario, crop yields are anticipated to be improved according to the government's short-term policy targets in Thailand's 15 years renewable development plan. In the high yield scenario, the crop yields are projected to reach the genetic potential of the cassava and sugar-cane varieties. Table 2 clearly shows that cassava feedstock will run out at some point in all the scenarios considered (indicated by the numbers in parentheses). The deficit could be made up by decreasing the export of cassava chips but that itself is an indicator of supply insecurity. Sugar-cane juice may play an increasingly important role in meeting the ethanol demand in the future as indicated by the high surplus availability of this feedstock.

One of implications of the results in Table 2 is that even if the ambitious moderate yield improvement scenario is achieved, there will still be a shortfall of cassava by 2016 and molasses by 2022. Therefore, expansion of both cassava as well as sugar-cane plantation areas needs to be considered if reduction of exports, which may in turn induce indirect effects of increased production elsewhere, is to be avoided. To produce bioethanol according to the government's targets and thus considering an expansion of cultivation areas for

sugar cane and cassava, five scenarios are postulated:

Case 1: New plantations for both cassava and sugar cane will take place on grassland.

Case 2: New plantations for both cassava and sugar cane will take place on forest land.

Case 3: Same as Case 1 but ethanol systems widely adopt sustainability measures such as waste utilization and biomass energy (Gheewala et al. 2011b).

Case 4: Same as Case 3 but new plantations of cassava and sugar cane take place on forest land.

Case 5: No expansion of new cultivated areas as cassava and sugar-cane yields are projected to increase to reach the genetic potentials of the current varieties. Sustainability measures adopted.

The results of the analysis are summarized in Table 3. It can clearly be seen that if no land area expansion takes place due to high yields (Case 5) or expansion takes place on grasslands (Cases 1 and 3), then bioethanol does better than gasoline even after inclusion of GHG emissions from direct land-use change. However, if forest land is converted to sugar-cane and cassava plantations (Cases 2 and 4), then the GHG benefits of bioethanol are lost due to the large emissions taking place due to land-use change (LUC). The GHG emissions per litre of ethanol range between 0.49-3.7 kg CO<sub>2</sub>-eq. The wide range is due to the effects of LUC as well as various production factors (waste utilization and biomass energy).

**Table 2. Net feedstock balances for bioethanol (after accounting for the projected demand)**

Net balance (Million tonnes feedstock/year)		2008	2009	2010	2011	2016	2022
Low yield improvement	Molasses	0.13	0.54	0.65	0.62	0.23	(0.17)
	Cassava	3.50	0.54	(2.11)	(3.61)	(13.00)	(20.95)
	Sugar cane		4.33	8.26	8.49	7.03	6.24
Moderate yield improvement	Molasses	0.13	0.81	1.13	1.31	0.81	(0.08)
	Cassava	3.50	1.23	0.64	1.19	(6.95)	(20.63)
	Sugar cane		10.24	18.75	23.55	19.60	8.23
High yield improvement	Molasses	0.13	0.81	1.13	1.31	1.42	1.44
	Cassava	3.50	1.23	0.64	1.19	(0.23)	(0.48)
	Sugar cane		10.24	18.75	23.55	32.79	41.18

Source: Silalertruksa and Gheewala (2010)

Note: Numbers in parentheses indicate shortfall.

**Table 3. GHG emissions of future bioethanol production systems in Thailand including LUC**

GHG indicator	Year	Case 1	Case 2	Case 3	Case 4	Case 5
Average GHG emissions from bioethanol (kg CO <sub>2</sub> -eq/L ethanol)	2011	1.39	1.39	0.48	0.48	0.48
	2016	1.75	3.16	0.76	2.18	0.49
	2022	1.84	3.7	0.85	2.71	0.49
GHG emission reduction compared to gasoline (%)	2011	27	27	74	74	74
	2016	8	(67)	60	(15)	74
	2022	3	(95)	55	(43)	74

Source: Silalertruksa and Gheewala (2011)

For the case of no new cultivated area (Case 5), in 2022, GHG reductions of 4.6 million tonnes CO<sub>2</sub>-eq (74 percent reduction compared to gasoline) are possible provided improvement options such as those suggested below are also encouraged:

- Increasing feedstock productivity by improving soil quality with organic fertilizers.
- Implementing energy conservation measures that promote use of renewable fuels in ethanol plants.
- Preventing cane trash burning during harvesting by using it as fuel in sugar milling.
- Enhancing waste utilization from ethanol plants such as biogas recovery, organic fertilizers and animal feed.
- Providing technical knowledge associated with cassava ethanol production to industry.

### Performance and prospects of biodiesel

Accounting studies of life cycle GHG emissions from biodiesel produced from palm oil and used cooking oil in Thailand have yielded values of 0.6-1.2 and 0.23 kg CO<sub>2</sub>-eq/L respectively which are much lower than an equivalent amount of conventional diesel (Pleanjai et al. 2009a; Pleanjai et al. 2009b; Silalertruksa and Gheewala 2012). The life cycle stages of the palm biodiesel chain are shown in Figure 4. The range of values for life cycle GHG emissions from palm biodiesel are due to variations in the production systems (energy carriers and waste/by-product utilization). The biodiesel produced from palm oil considered in the above study does not include land-use change (Stage 1) as the palm plantations in the southern region of Thailand have been in existence for over three decades. On the other hand, palm biodiesel in Southeast Asia has come under a lot of scrutiny due to conversion of tropical forests and peatlands, lands with high carbon

**Table 4. Net feedstock balances for biodiesel (after accounting for food and stocks)**

Net balance (million tonnes feedstock/year)	2008	2009	2010	2011	2016	2022
<b>Feedstock supply potentials</b>						
Planted area (million hectares)	0.58	0.67	0.75	0.83	0.91	0.91
Harvested area (million hectares)	0.46	0.51	0.55	0.59	0.91	0.91
Yield (tonnes/hectare)	20.2	18.6	19.7	20.8	21.9	21.9
FFB production (million tonnes FFB)	9.27	9.57	10.78	12.20	19.95	19.95
CPO production (million tonnes CPO)	1.68	1.74	1.96	2.22	3.63	3.63
<b>Feedstock requirements for biodiesel</b>						
Biodiesel production targets (million litres/day)	1.23	1.56	2.28	3.00	3.64	4.50
CPO required (million tonnes/year)	0.42	0.54	0.78	1.03	1.25	1.54
FFB required (million tonnes FFB/year)	2.32	2.94	4.30	5.66	6.87	8.49
<b>Net feedstock balances</b>						
Net CPO balance (million tonnes CPO)	0.15	0.09	0.03	(0.01)	0.88	0.07

Source: Silalertruksa and Gheewala (2012)

Note: CPO = crude palm oil.



stock, to oil-palm plantations which results in large release of GHGs. However, the situation in Thailand is quite different from the other palm oil-producing countries in the region in that there are hardly any peatlands and conversion of organic soils to oil-palm plantations is almost non-existent. Nevertheless, there are plans to expand plantations of oil-palm. Hence, it is interesting to evaluate the security of palm oil supply as it is by far the major feedstock for biodiesel, which types of land will be converted and what would be the consequences of such LUC on the GHG performance of biodiesel.

Table 4 shows the analysis of feedstock for biodiesel; if the government plan of yield increase and additional plantations is followed, there will not be a supply shortfall (Silalertruksa and Gheewala 2012). However, there is a chance of a slight deficit in 2010 and 2011. This is because even with additional plantations, fresh fruit bunches (FFB) can, at the earliest, only be harvested three years after planting. Hence, increase in productivity will be very important if imports are to be avoided. These will have to be supported by good agricultural practices such as application of appropriate amount of fertilizers, increased use of organic fertilizers and proper irrigation.

According to government plans, the expansion of oil-palm plantations will take place on abandoned rice fields, fruit orchards and reserved land. However, other site surveys have also shown conversion of rubber plantations, cassava and secondary forests to oil-palm (Siangjaeo et al. 2011). However, there is no evidence of tropical rain forests being converted to oil-palm plantations in Thailand. Five possible changes of land or cropping systems to oil-palm are presented

in Table 5. The conversion of forest to oil-palm is included only as a reference. Five different production systems are considered based on utilization of empty fruit bunches (EFB) and the wastewater from palm milling, termed palm oil mill effluent (POME), as follows:

*Case 1:* EFB is dumped in the plantation; POME is treated in open ponds with CH<sub>4</sub> leakage.

*Case 2:* EFB is dumped in the plantation; POME is treated with biogas recovery.

*Case 3:* EFB is co-composted with POME; POME is treated in open ponds with CH<sub>4</sub> leakage.

*Case 4:* EFB is co-composted with POME; POME is treated with biogas recovery.

*Case 5:* EFB is sold as fuel or other purposes; POME is treated with biogas recovery.

Compared to the life cycle GHG emissions from diesel (72 g CO<sub>2</sub>-eq/MJ), most of the scenarios even including LUC have GHG benefits. The conversion of forests to oil-palm have higher GHG emissions than diesel for every case indicating that utilization of waste/by-products cannot compensate for the GHG emissions from LUC. In fact, comparing the results with those excluding LUC indicates that conversion of field crops, rubber, paddy fields and reserved land to oil-palm actually has GHG benefits due to increase in biomass carbon stock and/or soil organic carbon. Converting reserved land to oil-palm plantation would intuitively have the maximum benefit; but this is not so as the calculations were done based on the assumption that reserved land would stock carbon as a grassland. This in a way reflects the opportunity cost of leaving the land uncultivated.

**Table 5. GHG emissions of future biodiesel systems in Thailand including LUC**

Land-use change scenario	GHG emissions of palm biodiesel (g CO <sub>2</sub> -eq/MJ biodiesel)				
	Case 1	Case 2	Case 3	Case 4	Case 5
Excluding LUC	38	20	21	18	20
Including LUC					
Rubber to oil-palm	25	6	8	5	6
Field crop to oil-palm	21	3	4	1	3
Paddy field to oil-palm	27	9	10	8	9
Reserved land to oil-palm	28	10	12	9	10
Forest land to oil-palm	248	230	231	228	230

Source: Silalertruksa and Gheewala (2012)

The above analysis shows that the government policy of expanding oil-palm plantation areas to non-forest lands and increase in yields can result in significant GHG benefits. Thus, the policy to promote suitable land as well as to encourage the implementation of recommended measures such as utilizing POME and EFB to produce biogas and co-compost and increasing FFB yield by promoting good agricultural practices to farmers is important and necessary for sustainable palm biodiesel production in Thailand.

### **Concluding remarks**

The analysis of feedstock availability in Thailand for bioethanol from cassava and sugar cane (including molasses) and biodiesel from palm oil has shown that if the government's targets on yield increases can be achieved along with careful expansion of cultivation areas, the planned targets for bioethanol (9 million litres /day) and biodiesel (4.5 million litres/day) in 2022 can be met. In addition, substantial GHG reductions can be achieved as compared to the gasoline and diesel that would be replaced in vehicles. Thus good agricultural practices must be urgently promoted by the responsible agencies and efforts made to utilize by-products from all the supply chains. The importance of by-product utilization to achieve the benefits points also to the need for developing the appropriate infrastructure (powerplants, biogas production facilities, fertilizer factories, etc.) so that the by-products can actually be utilized in practice.



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# Linking energy, bioslurry and composting

M. Fokhrul Islam<sup>1</sup>

## Introduction

Most Asian countries have largely agrarian societies. Therefore, any technology that can influence agriculture becomes a subject of concern, particularly in the domain of biogas.

In many Asian countries, the annual removal of soil nutrients is higher than what is added to the soil and with expanding areas under improved varieties and high-yielding crops, this removal is expected to continue at a higher rate in the future. As a result, the productivity of soils is declining due to this continuous over-mining.

To compensate for this development, the use of fertilizers has become the leading means to increase agricultural production. Yet it has not been possible to supply chemical fertilizer on time and at sites where it is required. In some cases, import of low-quality fertilizers has been reported. Continuous use of chemical fertilizer alone, without the addition of organic manure, has detrimental effects on soil quality in the long run mainly because of the constant loss of humus and micronutrients.



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Thus reliance on chemical fertilizer alone does not ensure sustainable agricultural development.

By-products of agriculture, mainly animal wastes and crop residues, are the primary inputs for biogas plants. Bioslurry, a biogas plant output, can be returned to the agricultural system. Proper application of bioslurry as organic manure/fertilizer improves soil fertility and thereby increases agricultural production because it contains elements of soil organic matter, plant nutrients, growth hormones and enzymes. Bioslurry can also safely replace part of animal and fish feed concentrates. Furthermore, bioslurry treatment increases the feed value of fodder with low protein content. When bioslurry is placed into the food chain of crops and animals, it leads to a sustainable increase in farm income.

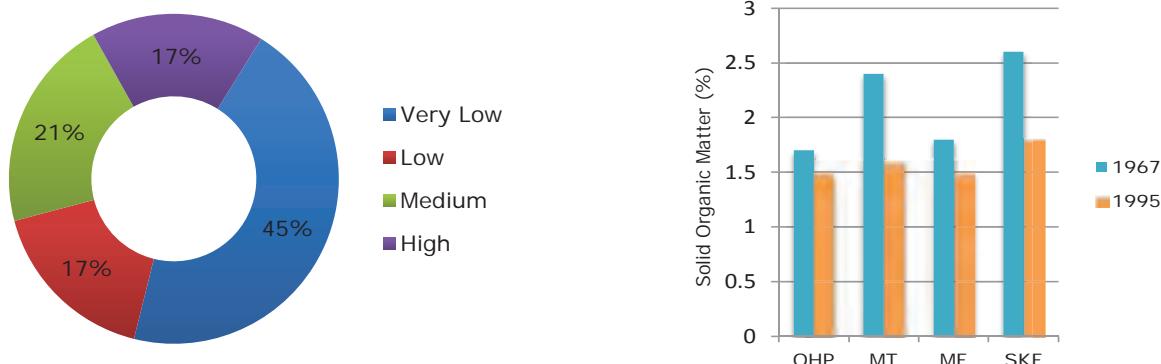
Bioslurry is linked with mitigation of natural resource use such as natural gas and is used for production of urea; in turn this saves natural gas used for production of electricity. Bioslurry use also reduces the need for mineral resources required for other fertilizers like triple super phosphate (TSP) and muriate of potash (MoP).

However bioslurry production needs energy for its drying, transportation and production of organic fertilizer and animal feed.



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**Figures 1a, b. Organic matter content and its change over time in Bangladesh**

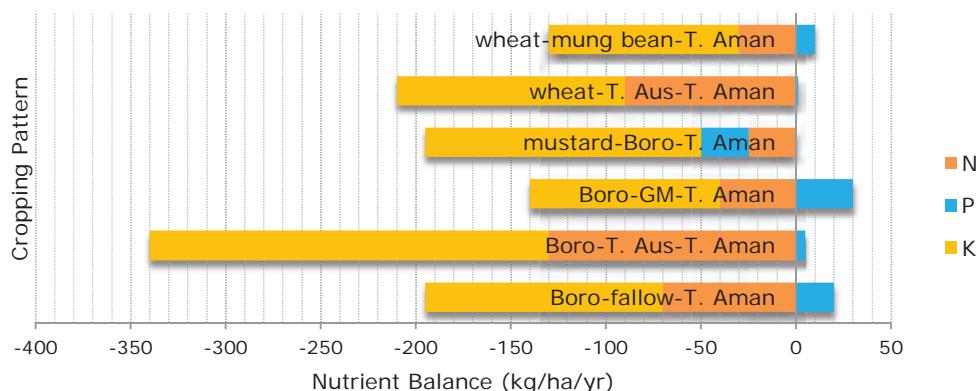


## Soil fertility in Bangladesh

Soil organic matter is the most important factor in soil fertility management. A good soil under Bangladeshi conditions should have organic matter content of 3.5 percent. But soil analysis shows that most soils (62 percent) have less than 1.5 percent and some even less than 1 percent (Figure 1a). One of the main reasons why crop productivity is declining in some areas is the depletion of soil organic matter over time (Figure 1b). This is caused by high cropping intensity, intensive tillage and removal of all straw and other crop residues from the field and practice of low organic manure application or none at all. Efforts must be made to educate farmers about the importance of soil organic matter, and the possibility of long-term soil improvement through application of more organic materials on fields.

The nutrient content of plants in Bangladeshi soil typically decreases over time. As time elapses, the nutrient balance is becoming more negative (Figure 2). Again, land use with higher cropping intensity may show higher negative balances. On the other hand, the addition of organic manure may help to reduce negative balances; the magnitude depends on the types and amounts of manure.

**Figure 2. Nutrient balance in different cropping patterns**



## Bioslurry

Bioslurry is the decomposed product of organic materials; it is derived from a reduction process in presence of anaerobic microbes in the digester of a biogas plant. It comes out through the hydraulic chamber of the biogas digester.

During digestion, about 25-30 percent of the total dry matter (total solids content of fresh dung) of animal/human wastes will be converted into a combustible gas, and a residue of 70-75 percent of the total solids content of the fresh dung comes out as sludge. It is this sludge that is known as digested slurry or bioslurry. Various names given for the digested slurry include: slurry, digested slurry, sludge, bioslurry, effluent slurry or biogas effluent, biomanure, organic fertilizers and organic manure.

## Source and form of bioslurry

The main sources of bioslurry are cow dung, poultry manure, buffalo dung and biodegradable agricultural waste. Bioslurry can appear in liquid, semi-dry and powder form.

## Characteristics of bioslurry

Some of the main traits and features of bioslurry are listed below:

- When fully digested, bioslurry is odourless and does not attract insects or flies in the open.
- Bioslurry repels termites but raw dung attracts them.
- Bioslurry reduces weed growth as biogas plants either destroy weed seeds or make them less fertile through anaerobic digestion.
- Bioslurry is excellent nutrient and feed material for algae, earthworms, livestock and fishponds.
- Bioslurry manure has greater fertilizer value than composted manure or fresh dung.
- Bioslurry is an excellent soil conditioner as it adds humus and supports the microbiological activity in the soil, increasing the soil porosity and water-holding capacity.
- Bioslurry has residual value (whereas most chemical fertilizer is effective for one crop only).
- Bioslurry is pathogen-free. The complete digestion of dung in a biogas plant kills the pathogens present in it.
- Bioslurry can be used to compost other raw materials and this provides larger quantities of manure.
- Loss of nitrogen is lower in the case of bioslurry compared to fertilizers and compost due to anaerobic conditions in the biogas plant.
- If night soil (toilet attached) and cattle urine is added, N and P availability in the bioslurry manure can be increased.

## Potential of bioslurry use

For the promotion of biogas technology, besides gas, the potential of bioslurry use has to be taken into consideration. There is a need to understand and assess the potential of bioslurry in terms of maintaining soil fertility, reduction of inorganic fertilizers and agricultural production.

## Maintaining/improving soil fertility

Decline in soil fertility is a common scenario in most countries though magnitudes vary in different agro-ecological zones (AEZ) within a country. Decline in soil fertility describes deterioration in physical, chemical and biological properties. It occurs through

a combination of lowering of soil organic matter and loss of nutrients. The average organic matter content of topsoil in Bangladesh has declined by 20-46 percent over the past 20 years, due to intensive cultivation of the land. To arrest further decline of soil fertility, proper use of bioslurry alone or in combinations with inorganic fertilizers may be good options.

Bioslurry obtained as a result of anaerobic decomposition from a biogas plant may be considered as a high-quality organic fertilizer. This organic fertilizer is environmentally friendly, has no toxic or harmful effects and can help to a great extent to rejuvenate soils by supplying considerable amounts of macro- and micronutrients and organic matter, which can also improve the physical and biological conditions of the soil.

This organic fertilizer also has liming effects. Poultry litter-fermented organic fertilizer is more effective in acid soils to reduce acidity, and thereby protects crops from the harmful effects of aluminium. Cowdung, poultry bioslurry and bioslurry compost can be fitted into the modern Integrated Plant Nutrition System (IPNS), which combines the use of organic and chemical fertilizers. Thus, the use of bioslurry will improve the physical, chemical and biological conditions of the soil.

## Reduction of inorganic fertilizer use

There is potential for establishing about 3 million biogas plants in Bangladesh and the possibility of producing 18 million tonnes of dry bioslurry (15 percent moisture) per year from family-sized (2.4 m<sup>3</sup>) biogas plants. If calculated in terms of nutrients, 207 000 tonnes of nitrogen, 111 000 tonnes of phosphorus and 28 518 tonnes of potassium would be available each year as fertilizer.

A family-sized biogas plant produces 6 tonnes (dry basis) of bioslurry per year, which can supply nutrients to the equivalent amount of 163 kilograms of urea, 280 kilograms of TSP, 162 kilograms of potash and 245 kilograms of gypsum.

If properly managed, bioslurry could play a major role in supplementing the use of expensive inorganic fertilizers. However, in the present context in Asia, the focus has been only to increase the number of biogas plants for its gas use and little attention has been paid to the proper utilization of bioslurry as organic fertilizer.



## Increasing agricultural production

Bioslurry can be used successfully for crop production owing to its good quality plant nutrient value. But its effectiveness depends on cropping systems, crop variety to be used, soil types and agro-ecological regions. Neither bioslurry nor inorganic fertilizer alone is enough to meet the demands of soil-crop systems.

The farmer needs to use chemical fertilizer to increase crop production. However, if only mineral fertilizers are continuously applied to the soil without adding organic manure, the productivity of the land will decline. On the other hand, if only organic manure is added to the soil, desired increase in crop yield cannot be achieved. Fertility trials carried out in Bangladesh and elsewhere have revealed that optimum results can be achieved through the combined application of both chemical and organic fertilizers following the IPNS approach.

In countries where biogas technology is well developed, for instance in China, there is evidence that productivity of agricultural land can be increased to a remarkable extent with the use of bioslurry produced from a biogas plant.

In Bangladesh, the Bangladesh Agricultural Research Institute (BARI) with support from the SNV (Netherlands Development Organisation) conducted on-station and on-farm trials with bioslurry on different crops in major AEZs; average crop yield increases are given in Table 1.

## Agribusiness

Bioslurry can be used effectively for all high-value fields and horticultural crops including vegetables, fruit, flowering as well as ornamental plants and roof-top gardens. This organic fertilizer can also

profitably be used for forest nurseries, public parks and roadside plantations.

Organically-produced crops and fruits are healthy and nutritious, and have better shelf-life as well as higher market value. Demand for organically-produced crops is increasing in Bangladesh and elsewhere in the world.

## Quality organic fertilizer

A part of the total content of plant nutrients in bioslurry is converted to available form and if liquid bioslurry is applied to a standing crop, it can immediately absorb these nutrients. Bioslurry can be applied directly to the fruit or vegetable crops grown close to the house or biogas plant with the help of a bucket or pail.

## Bioslurry for composting

Using dry forms of bioslurry is not recommended. The transportation of fresh slurry is not that practical because farmers want to fertilize all their fields at several sites. The slurry comes daily from the biodigester but cannot be used daily because farmers use manure according to cropping seasons. Thus it needs to be preserved and used as and when needed. However it is also noted that crop yields are decreasing because not enough organic manure is being added. Similarly, much agricultural waste such as weeds, straw and crop residues are being burned and not used properly. One remedy is to make compost. Bioslurry is the best material to make compost as it contains micro-organisms that are very helpful in the decomposition of organic wastes. The slurry need not be decomposed as it has already been digested during gas formation, and can thus be used directly. However, to use it when needed, and to increase the quantity of manure, it should be composted and stored safely. Composting can be done via pit or heap methods.

Table 1. Crop yield increases with bioslurry in Bangladesh

Crop	% yield increase with IPNS over inorganic fertilizer	
	Cowdung bioslurry	Poultrymanure bioslurry
Boro rice	9	-
Wheat	17	-
Maize	17	-
Cabbage	16	-
Cauliflower	21	-
Tomato	-	19
Potato	12	-
Mustard	8	-
Jute	4	-

Source: BARI project report 2008 & 2009

## Material for composting

Material with a high C: N ratio such as sawdust (Table 2) should not be used for composting. Composting increases the nutrient content (Table 3) and quantity of biomanure. The amount of compost depends on the amount and type of organic materials added. Generally the amount of compost is three times higher than that of bioslurry.

## Potential use of bioslurry or other purposes

In addition to its application as manure/fertilizer or compost preparation, bioslurry has many other uses such as for:

- Soil conditioning;
- Feed;
- Pesticide;
- Seed pelleting;
- Animal feed;
- Fish culture;
- Mushroom cultivation; and
- Earthworm rearing (vermiculture).

**Table 2. Material for composting**

Items	C: N ratio
Dry leaves	-
Kitchen waste	-
Animal bedding	-
Water hyacinth	25
Maize stalks	60
Rice straw	70
Wheat straw	90
Sawdust	200
Paddy husks	250

**Table 3. Nutrient content of bioslurry and its compost**

Compost materials	Nutrient content (%)			
	N	P	K	S
Cowdung slurry	1.42	0.68	0.32	0.33
Cowdung slurry compost	1.73	0.85	0.37	0.46
Poultry manure slurry	1.85	0.88	0.52	0.40
Poultry manure slurry compost	2.38	0.95	0.77	0.38

## Bangladesh Government Gazette for Organic Fertilizer

The Government of Bangladesh has approved permissible limits for organic fertilizer (Table 4).

**Table 4a. Permissible limits of different nutrients in organic manure**

	pH	%	N	P	K	S	Cu	Fe	Mn	Zn
Minimum	6.0	17	0.50	0.5	1	0.1	0	-	-	0
Maximum	8.5	43	4.00	1.5	3	0.5	0.050	-	-	0.10

**Table 4b. Permissible limits of different heavy metals in organic manure**

Permissible limit	% moisture	Co	Ni	µg/g		
				Cd	Pb	As
Minimum	0	-	0	0	0	0
Maximum	15	-	30	5	30	20

## Bioslurry quantity and quality

### Quantity of bioslurry in comparison with farmyard manure

The quantity of manure after processing through a biogas plant exceeds that of farmyard manure. About 25-30 percent of organic matter present in dung is converted into gas while about 50 percent of the organic matter is lost in open pit composting as carbon dioxide. Thus about 20 to 25 percent more manure is produced through a biogas plant. Secondly, the quantity of bioslurry manure can be increased up to three times its weight if composting is done at the rate of 1: 3 ratios of bioslurry and agricultural waste or dry materials. A research study has shown that the quantity of organic manure obtained from composting bioslurry out of biogas plant is 40-45 percent more than traditional pit manure. A threefold increase in the quantity of manure can be achieved if bioslurry is composted with organic dry materials available in and around the farm.

### Plant nutrient value of bioslurry

The National Domestic Biogas and Manure Program supported by SNV outsourced its bioslurry research activities to BARI. An investigation was conducted by BARI to determine manure quality for bioslurry. Bioslurry samples were collected from biogas plants. Samples were analysed for moisture content, pH, organic matter, essential plant nutrients (N, P, K, Ca, Mg, S, B, Cu, Fe and Mn) and heavy metals like Co, Ni, Cd and Pb.

All samples contained more than 17 percent organic matter (Table 5). The nutrient content of poultry manure bioslurry was higher than that of cowdung bioslurry. The calcium content of poultry manure

bioslurry was higher than cowdung and buffalo dung bioslurry because poultry feed contains more calcium. This high content of calcium is useful for decreasing the acidity of acidic soils.

Cobalt, nickel and cadmium contents of cowdung and poultry manure bioslurry were within the safe limit (Table 6). The lead concentration of poultry bioslurry was higher than that of cowdung bioslurry. Air-dried bioslurry contained higher organic matter and nitrogen than sun-dried bioslurry.

## Bioslurry research and extension

### On-station trials

Two separate experiments were conducted under irrigated conditions. Six treatments were replicated three times in a randomized complete block design for high yields:

- $T_1$ : Soil test based (STB) inorganic fertilizer;
- $T_2$ : IPNS with 5 tonnes/hectare cowdung plus inorganic fertilizer;
- $T_3$ : IPNS with 5 tonnes/hectare cowdung bioslurry plus inorganic fertilizer;
- $T_4$ : IPNS with 3 tonnes/hectare poultry manure plus inorganic fertilizer;
- $T_5$ : IPNS with 3 tonnes/hectare poultry bioslurry plus inorganic fertilizer; and
- $T_6$ : Natural fertility (no fertilizer used).

The details of the materials and methods used in the experiments are available in the project annual report 2009 and 2010.

**Table 5. Organic matter and nutrient content of bioslurry**

Manure	OM (%)	Nutrient concentration (%)						
		N	P	K	S	Ca	Mg	
Cowdung bioslurry	27	1.42	0.68	0.32	0.33	1.41	0.85	
Poultry manure bioslurry	29	1.85	0.88	0.52	0.40	5.72	1.98	
Buffalo dung bioslurry	26	1.05	0.82	0.55	0.44	1.15	1.11	

**Table 6. Heavy metal status of different organic manure**

Sources	$\mu\text{g/g}$			
	Co	Ni	Cd	Pb
Cowdung bioslurry	7.2	9.4	0.9	9.1
Poultry manure bioslurry	8.2	10.3	1.0	24.5
Buffalo dung bioslurry	5.3	7.9	0.4	4.8

The type of nutrient package significantly influenced the yield and yield components of cabbage and cauliflower. The highest head yield of cabbage (98.3 tonnes/hectare) and curd yield of cauliflower (56.8 tonnes/hectare) were obtained from  $T_5$  which was close to  $T_3$ . The gross margin was higher where organic and inorganic fertilizer were used combined compared to that of  $T_1$  while the marginal benefit-cost ratio (MBCR) was higher in  $T_4$  (Table 9).

### On-farm trials

On-farm trials were conducted with five vegetable crops (cabbage, cauliflower, brinjal, tomato and potato), three cereal crops (maize, wheat and rice), 1 fibre crop (cash crop) and 1 oilseed crop (mustard) in 110 farmers' fields in 30 locations of Bangladesh.

Four nutrient management packages –  $T_1$  (STB inorganic fertilizers),  $T_2$  (IPNS with poultry manure/cowdung),  $T_3$  (IPNS with poultry bioslurry/cowdung bioslurry) as well as the farmers' dose (not in all locations) were tested on different crops (Table 10).

Use of bioslurry increased yield of:

- Energy-rich food crops: wheat, rice (9-16 percent);
- Biofuel-producing plants/crops: maize (17 percent), Jatropha, rubber;
- High-value vegetable crops: cabbage, cauliflower, tomato (11-48 percent); and
- Cash crops: jute (4 percent), tea

**Table 7. Effect of different nutrient packages on the yield and MBCR of cabbage and cauliflower**

Treatment	Cabbage		Cauliflower	
	Head yield (tonnes/ hectare)	MBCR	Curd yield (tonnes/ hectare)	MBCR
$T_1$ : STB inorganic fertilizer	83.9c	24.83	41.9d	13.76
$T_2$ : IPNS with 5 tonnes/hectare cowdung	87.2bc	31.01	47.5cd	21.35
$T_3$ : IPNS with 5 tonnes/hectare cowdung slurry	96.1ab	16.83	54.1ab	11.03
$T_4$ : IPNS with 3 tonnes/hectare poultry manure	88.5bc	34.53	49.7bc	25.44
$T_5$ : IPNS with 3 tonnes/hectare poultry manure slurry	98.3a	20.51	56.8a	14.32
$T_6$ : Natural fertility	21.4d	-	15.4e	-

**Table 8. Effect of nutrient management practices on various crops**

Treatment	Cabbage	Cauliflower	Brinjal	Tomato	Maize	Wheat	Mustard	Rice <sup>1</sup>	Jute
	Yield (tonnes/hectare)								
Inorganic fertilizers	91.4	39.2	57.2	87.9	7.7	3.2	1.2	6.8	2.7
IPNS with manure	92.8	44.6	84.9	95.0	8.0	3.5	1.2	6.9	2.7
IPNS with bioslurry	106.3	47.3	108.9	104.6	9.0	3.8	1.3	7.5	2.8
Farmers' practice	78.8	37.4	49.9	77.8	7.6	3.1	1.0	6.2	2.6

### Bioslurry extension

Bioslurry extension activities are outsourced to the Department of Agriculture Extension (DAE). The following activities have been undertaken:

- Activity 1. Development of extension materials;
- Activity 2. Training; and
- Activity 3. Demonstration.

The following demonstrations were conducted:

- Slurry compost preparation and preservation;
- IPNS;
- Home garden management.
- Activity 4: Farmers' Field Day on Bioslurry Management and Utilization.

### Linking bioslurry and energy

Bioslurry is a source of energy for soil micro-organisms to break down complex organic materials and release nutrients into the soil.

Use of bioslurry as organic manure or fertilizer saves a considerable amount of inorganic fertilizers and thereby saves on exploitation of natural resources for the production of fertilizer. It also saves on required for the production of inorganic fertilizers and natural resources like methane for the production of energy.



- Bangladesh has potential (in terms of input sources) of establishing 3 million domestic biogas plants;
- 1 plant (size 2.4 m<sup>3</sup>) produces 6 tonnes of dry bioslurry annually;
- Bangladesh can produce 18 million tonnes of dry bioslurry annually;
- 18 million tonnes of dry bioslurry can supply nutrients equivalent to 0.57 million tonnes of urea, 0.61 million tonnes of TSP, 0.12 million tonnes of MoP and 0.33 million tonnes of gypsum annually;
- Producing 0.57 million tonnes of urea in factories requires 19 380 mmcfc CH<sub>4</sub>;
- 19 380 mmcfc CH<sub>4</sub> gas can generate 200-220 MW;
- 18 million tonnes of dry bioslurry can save US\$643 million annually on the cost of fertilizers (non-subsidized basis);
- If a Bangladeshi farm household has a biodigester (2.4 m<sup>3</sup>) it can save US\$148 by using bioslurry.

The use of bioslurry can save draught power and energy for land preparation by decreasing the soil bulk density.

Bioslurry needs energy via sun-drying or mechanical/electrical driers. Sun-drying is not advisable because of loss of quality, such as loss of nitrogen.

Bioslurry as organic manure or organic fertilizer needs energy for transport to remote locations.

## Future needs

### Research

Further research needs to be conducted on:

- Bioslurry quality;
- Mineralization and nutrient-release patterns;
- Residual value;
- Storage;
- Energy needs for transportation and drying;
- Use of bioslurry as fish and animal feed;
- Standardization of liquid bioslurry for use in crop and fish culture; and
- Exploration of the commercial potential for using bioslurry as organic fertilizer.

### Extension

Strengthen extension (public, NGO and private) activities to increase the capacity building of biogas plant owners and bioslurry users in relation to proper bioslurry management and utilization.

### Conclusion

Bioslurry is important for maintaining soil health and thereby increasing crop yield. It has salient environmental traits as it draws heavily upon by-products of biogas production that otherwise would largely remain unused. Bioslurry can mitigate the use of natural resources and energy and represent a source of income for farm households. Bioslurry needs energy for drying and transportation. The use of bioslurry in Asia is still at a nascent stage and different aspects of its values still need further investigation.



# Biochar potential for Asia and the Pacific

Yoshiyuki Shinogi<sup>1</sup>

## Introduction

Biochar is a carbon product obtained from biomass. Wood-char has been widely used as a solid fuel worldwide, and for many other purposes in Japan, mainly for soil amendment and as a humidity control resource and as an ornament in houses. Recently, biochar has been used as a stable carbon sink in farm fields. However, there is little solid evidence that it is a stable, long-lasting carbon sequester. This needs rectification to allow it to reach its full potential. In Southeast Asia, the possibility for viable biomass production is considerable, but this has yet to be fully realized. Promotion in this context is necessary for sustainable agricultural production and rural development.



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## The nature of biochar

### Characteristics

Biochar is light and highly absorbent. During pyrolysis, reduction of weight and volume, noxious odours such as ammonium fumes and dioxin emissions occurs in greater volume compared to usual incineration, depending on the feed material and manufacturing conditions, such as, temperature and furnace conditions.

Wood-char is reported to contain potassium, which is an essential nutrient for crops; some kinds of biochar, mainly from cattle waste and sewage sludge, contain nutrients. Shingyoji et al. (2009) reported that citric phosphorus and potassium are contained in biochar from sewage and cattle waste(sludge); thus, it can replace or reduce chemical fertilizer applications on farmland.

### Use

Application of biochar can improve the soil's physical and mechanical properties such as water-holding capacity, hydraulic conductivity, and soil compaction. Thus, we can expect to improve root zone conditions not only for crops, but also, for microorganisms in adjacent crop root zones.

It can also be used as an effective deodorant to absorb various noxious odors, such as; ammonium fumes from livestock manure and for moisture control in humid areas.

<sup>1</sup> Professor, Kyushu University, Fukuoka, Japan, Vice-President, Japan Biochar Association, Board Member, International Biochar Initiatives.

## Carbon sequestration

Biochar, mainly wood-char, has been employed in Japan since ancient times. Evidence of this has been found at archeological sites and in historical records. It is believed that under certain conditions it does not decompose easily; consequently, it provides long lasting benefits. However, there are currently no precise methods for analyzing carbon that does not decompose easily.

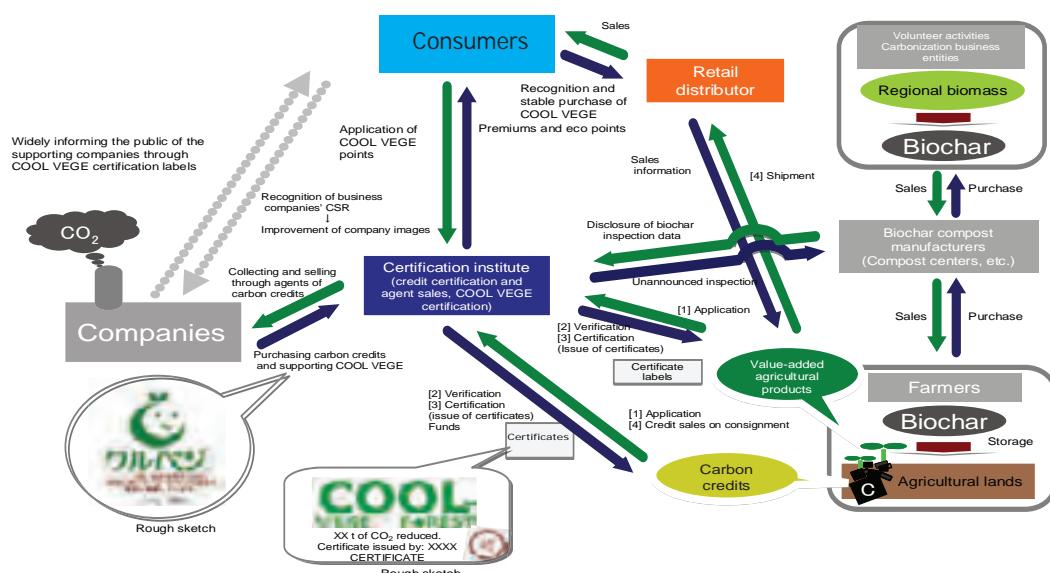
Pyrolysis during biochar production fixes carbon; therefore, biochar can act as a stable carbon sink on farmland. It improves the productivity of the farmland as it facilitates the absorption of CO<sub>2</sub> by crops from the atmosphere through photosynthesis. We can expect more CO<sub>2</sub> to be absorbed by plants that grow in fields applied with biochar. Recent research indicates that it can be considered a stable and effective carbon sink.

However energy is needed to produce biochar, so how can carbon can be sequestered in a stable and sustainably manor, with little or no energy input, is a major issue to be addressed.

## Carbon sequestration programmes in Japan

The Ministry of Agriculture, Forestry and Fisheries in Japan has launched carbon sequestration programmes from 2009 for three years. Sixteen programmes have been approved nationwide. Six programmes deal with carbon products such as biochar, namely Aomori, Akiruno (Tokyo), Hozu (Kyoto), Higashiommi (Shiga), Kochi, and Miyako (Okinawa).

Figure 1. The Carbon Minus Project at Hozu (Kyoto)



Source: McGreevy and Shibata (2010)

Figure 1 illustrates an innovative example of carbon stably sequestered by applying biochar in fields according to a standard, and selling them as certified carbon minus vegetables to revitalize a local economy.

This certified vegetable is sold under the trade marked name 'Cool Vege', and is accompanied by a 'Cool Vege' certification label. Participating private companies provide funding as a means to promote their Corporate Social Responsibility (CSR) activities, and in return receive feedback from Cool Vege customers that have purchased those products. The farmers who applied biochar to their fields also benefit through subsidies from the private fund. This programme has been extended to other regions and to other companies. This is the first programme in which biochar use has been activated to support rural regions.

The most important task is acquiring official certification. In this context The Japan Biochar Association (JBA) has been striving to achieve biochar certification, biochar inputs, and product quality. Environmental education is also included in this programme. Farmers' associations invite elementary schools to send pupils to participate in farming activities, such as, treading wheat in winter. Environmental conservation is thus promoted, and the children enjoy the activity as well.

## Conclusion

Much remains to be done for biochar to be approved as a sustainable carbon sink by the international community, so further research is required to support stability, standardization, and quality.

In September 2011 the Asia and the Pacific Biochar Conference was held in Kyoto, organized by the JBA. In-depth discussion and information was exchanged, and it is hoped that future exchanges will promote consolidation of biochar research and its use on a global scale.

## Acknowledgement

The author gives special appreciation to Dr. Akira Shibara (Ritsumeikan University, Kyoto, Japan) and Dr. Michael Hall (Kyushu University, Fukuoka, Japan) for information and assistance in writing this article.





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# SECTION V: ANNEXES

## Annex 1

### Programme - Sustainable Bioenergy Symposium: Improving resilience to high food prices and climate change

**June 2, 2011**

Renewable Energy Asia 2011, BITEC, Bang Na.

#### **Objective**

The objectives of the Symposium are:

- a. To share experiences with initiatives around the region designed to improve the sustainability of regional bioenergy production;
- b. To identify suitable technologies and strategies to foster more sustainable and effective bioenergy systems in Asia; and
- c. To create opportunities for more effective future collaboration in the development of sustainable bioenergy technologies and policies.

## Participants

The Symposium will include presentations from over 35 technical and policy experts from the Asian bioenergy sector. The Symposium is open to all registered participants at Renewable Energy Asia 2011.

## Theme and format

The theme for the symposium is 'Improving resilience to high food prices and climate change'. As part of the program the organizers will showcase a number of emerging approaches to ensure that bioenergy developments in Asia avoid conflicts with food security and deliver on their potential benefits for rural development, the environment and the climate. By combining the Symposium with the annual Renewable Energy Asia event, FAO is looking to create a unique forum for government representatives, the development community and the private renewable energy sector to identify ways to provide more sustainable and effective bioenergy systems and policies in Asia.

The Symposium will be organized into five sessions to encourage more focused discussion on issues related to the central theme. As some sessions will be convened simultaneously, participants are encouraged to identify sessions where they feel their particular knowledge and expertise will be most relevant to the discussions. However, it will be possible to also float between sessions depending on where each individual participant's interests lie.

The Symposium sessions are:

- Session 1: Opening and Keynote address
- Session 2: Plenary session on 'Ensuring bioenergy is not a threat to food security and the climate in Asia'
- Session 3: Group session on 'Sustainable bioenergy feedstock production in Asia'
- Session 4: Group session on 'Expanding the reach of sustainable rural bioenergy solutions in Asia'
- Session 5: Group session on 'Climate friendly bioenergy'

## Final Programme

Time	Item and Speaker / Organization
<b>Session 1</b>	<b>Welcome</b>
09:00 – 09:10	Welcome Address – Mr. Hiroyuki Konuma, FAO Regional Representative for Asia and the Pacific and Assistant Director-General, FAO RAP
09:10 – 09:20	Welcome Address – Dr. Bundit Fungtammasan, JGSEE
09:20 – 09:40	Bioenergy outlook in Asia and the FAO integrated approach/tool on bioenergy and food security by Mr. Beau Damen, FAO Asia Pacific
09:40 – 10:00	A regional framework for bioenergy and food security in Southeast Asia and East Asia by Ms. Pouchamarn Wongsanga, ASEAN Secretariat
10:00 – 10:30	Coffee Break
<b>Session 2</b>	<b>Panel debate</b>
10:30 – 11:30	<b>Topic: Ensuring bioenergy is not a threat to food security and the climate in Asia</b> <b>Moderator: Mr. Beau Damen, FAO</b>
	<b>Speakers discuss topic for 10-15 minutes followed by questions from the moderator and the audience.</b>
	<b>Possible selection of speaker topics:</b>
	The potential of bioenergy to benefit the environment and food production systems by Dr. Boonrod Sajjakulnukit, JGSEE
	Small-scale bioenergy systems: Finding a local way to generate energy, strengthen communities and benefit the environment by Mr. Bastiaan Teune, SNV
	Linking bioenergy, natural resource management and climate change by Dr. Sitanon Jesdapipat, SEA START

Investigating the links between bioenergy and food security by Professor Sudip Rakshit, Asian Institute of Technology

11:30 – 12:00 Question and answer session by Panel Speakers  
12:00 – 13:00 Lunch

**Session 3** **Parallel breakout sessions**

**Topic 1: Bioenergy & food security: Using our resources more sustainably**

**Moderator: Ms. Delgermaa Chuluunbatar, FAO**

13:00 – 13:30 Integrated food and energy systems: A local way to improve food security by Ms. Delgermaa Chuluunbatar, FAO

13:30 – 14:00 Tropical agriculture and bioenergy in Asia by Mr. Rod Lefroy, International Centre for Tropical Agriculture (CIAT)

14:00 – 14:30 Biofuels and consumptive water use by Mr. Upali Amarasinghe, International Water Management Institute

14:30 – 15:00 Coffee break

**Breakout Group Panel Session**

**Topic: Sustainable bioenergy feedstock production – examples from the region**

**Moderator: Ms. Delgermaa Chuluunbatar, FAO**

**Speakers discuss topic for 10-15 minutes followed by questions from the moderator and the audience.**

**Selection of speaker topics:**

Increasing cassava productivity for food and bioenergy production on small-holder farms by Thailand National Science and Technology Development Agency by Dr. Kuakoon Piyachomkwan, NSTDA

Sustainable palm oil initiative in Thailand by Mr. Daniel May, GIZ

Profitability of Social Investing – a case study in sustainable Jatropha production in Vietnam by Mr. Jamey Hadden, Green Energy Vietnam

An assessment of different bioenergy feedstocks in Thailand by Dr. Suthiporn Chirapanda, Thai Tapioca Development Institute

Sweet sorghum: A better feedstock for bioenergy in Asia? by Mr. Shi Zhong Li, Tsinghua University

Technical and economic prospects of rice residues (husks and straw) for energy in Asia by Dr. Werner Siemers, CUTEC Institute

16:00 – 16:30 Question and answer session by Panel Speakers  
Session End

**Session 4** **Topic 2: Expanding the reach of sustainable rural bioenergy solutions in Asia**

**Moderator: Mr. Sverre Tvinneim, FAO**

13:00 – 13:30 Enhancing the use of bioenergy to enrich rural livelihoods: Examples from Asia by Mr. Sverre Tvinneim, FAO

13:30 – 14:00 A good start: Energy needs assessments for rural bioenergy projects by Dr. Kanchana Sethanan, Khon Kaen University

14:00 – 14:30 Making energy services work for the poor in Asia by Mr. Thiagarajan Velumail, UNDP Regional Centre, Asia-Pacific

14:30 – 15:00 Coffee break

**Breakout Group Panel Session**

15:00 – 16:00      **Topic: How to make more effective policies and financing arrangements for rural bioenergy**  
**Moderator: Mr. Sverre Tvinnereim, FAO**

**Speakers discuss topic for 10-15 minutes followed by questions from the moderator and the audience.**

**Selection of speaker topics:**

Challenges and opportunities for financing rural bioenergy projects: Examples from Lao PDR by Ms. Aurelie Phimmasone, Lao Institute of Renewable Energy

Potential for social indicators to guide bioenergy policies by Dr. Sittha Sukkasi, NSTDA

Developing small-scale, environmentally sustainable bioenergy technologies in Myanmar by Mr. Htun Naing Aung, KKS

Developing opportunities for public private partnerships in rural bioenergy by Eco-Asia by Mr. Suneel Parasnus, Eco-Asia

Possibilities for using microfinance for farm/household level bioenergy technologies by Dr. Riaz Kahn, AIT Yunus Centre

16:00 – 16:30      Question and answer session by Panel Speakers  
Session End

**Session 5      Topic 3: Climate friendly bioenergy**

**Moderator: Mr. Beau Damen, FAO**

13:00 – 13:30      Climate friendly bioenergy and food security in the Greater Mekong Sub-region by Ms. Sununtar Setboonsarng, Asia Development Bank

13:30 – 14:00      Current status and prospect of biofuels in Thailand by Professor Shabbir Gheewala, Joint Graduate School of Energy and Environment

14:00 – 14:30      Integrating Feed-in-Tariff Policy into a PoA: Case Study from Thailand by Mr. Ingo Puhl, South-Pole Carbon

14:30 – 15:00      Coffee break

**Breakout Group Panel Session**

15:00 – 16:00      **Topic: Innovative, climate friendly bioenergy**

**Moderator: Mr. Beau Damen, FAO**

**Speakers discuss topic for 10-15 minutes followed by questions from the moderator and the audience.**

**Selection of speaker topics:**

Linking bioenergy, bioslurry and composting by Dr. Fokhrul Islam, SNV

Zero Waste Concept in Cassava Starch Industry: Implementation of biogas technology and Improvement of production process efficiency by Dr. Warinthon Songkasiri, NSTDA

Biogenious Waste to Biogas – Challenges and Solutions by Dr. Gert Morscheck, Rostock University

Potential for biochar from bioenergy in Asia and the Pacific by Dr. Shinogi Yoshiyuki, International Biochar Institute

Accessing carbon markets with small-scale biogas technologies by Mr. Oliver Lefebvre, ID China

16:00 – 16:30      Question and answer session by Panel Speakers  
Session End



Patterns in the use of bioenergy have been a key indicator of changing fortunes in Asia. Formerly the key source of energy for the region's largely agrarian societies, rapid economic development over the past 50 years has resulted in a significant decline in bioenergy's share of total primary energy and replacement with fossil energy. This transition has opened up even further opportunities for development and change.

Despite the overall trend toward fossil energy in the region, high fossil energy prices and a growing need for more environmentally sustainable energy sources have encouraged many governments in the region to adopt policies to support the development of modern bioenergy sectors. But, the recent resurgence of agricultural commodity prices in the region has given renewed cause to question whether a sustainable expansion of biomass feedstock to satisfy both the regional energy needs of growing economies and food requirements of growing populations is, in fact, possible. The region's capacity to produce increased biomass resources for food and fuel over the long-term will be further complicated by the anticipated impacts of climate change.

This publication documents recent experience with sustainable bioenergy in Asia. It highlights a number of approaches to strengthen the resilience of the region's biomass production systems, improve the contribution of bioenergy to rural development and avoid harmful trade-offs.

ISBN 978-92-5-107291-2



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