RAP Publication 2012/14

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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Printed and published in Bangkok, Thailand

ISBN 978-92-5-107291-2

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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.

Sustainable Bioenergy in Asia:
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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 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[1]

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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.

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)[2]. 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.

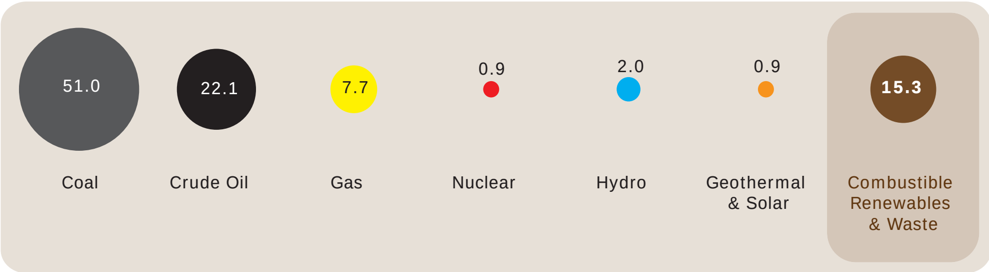
Bioenergy supply and consumption

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).

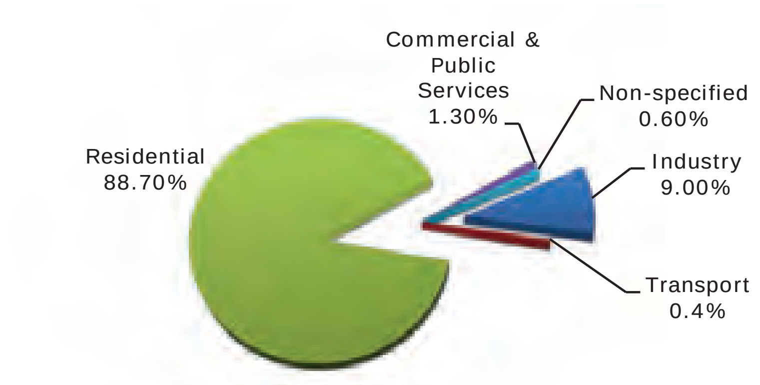
At the regional level, consumption of bioenergy is dominated by the residential sector, reflecting the high proportion of people in the region who still rely on traditional bioenergy for basic energy services such as cooking and heating (Figure 2).

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.

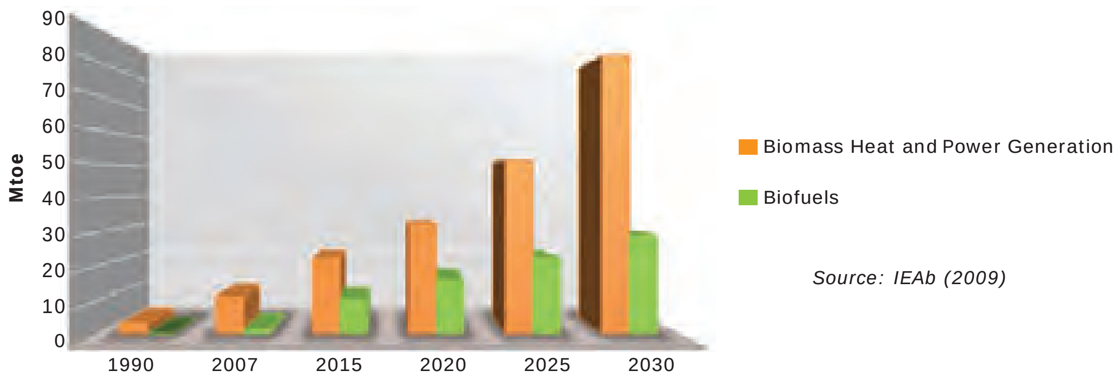
The effect of these policies could be substantial. According to the IEA, over the next 20 years power generation from biomass and wastes in non-OECD Asia is projected to grow at 12.3 percent *per annum*, while biofuel consumption in the transport sector

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



Source: IEAb (2009)

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_2 emissions per capita have grown by an average rate of 3.2 percent *per annum*. Total regional emissions of CO_2 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 (IEAb 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 ligno-cellulosic 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..

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 <u>coordinated</u> 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[1]


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Introduction

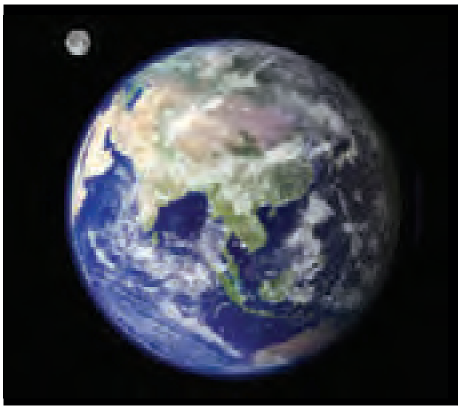
Energy poverty prevails for half of the world's population and poses severe consequences for women's livelihoods especially. Exposure to smoke from traditional biomass burning for cooking and heating causes 2 million premature deaths annually. This situation can change dramatically through mass dissemination 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

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

1 SNV Renewable Energy Sector Leader in Lao PDR

Plate 2. The world by night

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).

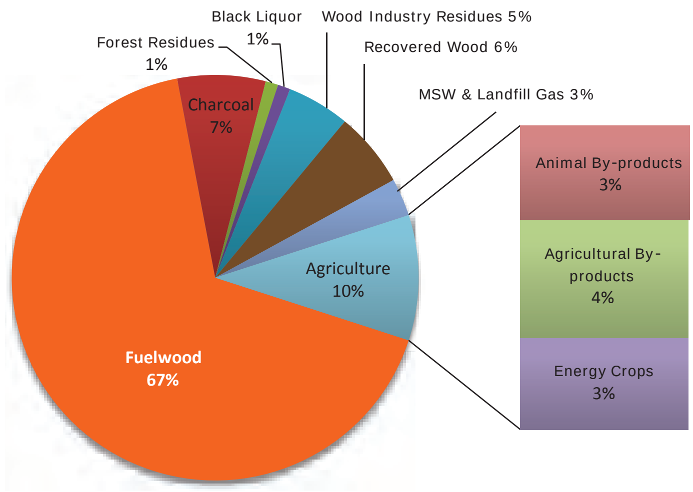
However in the context of quality of life worldwide, the alarming conclusion is that one-third of its population does not have access to electric light. *Vis-à-vis* thermal energy, 2.7 billion people cook with traditional solid fuels instead of gas and electricity and live in darkness. Collection of 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.

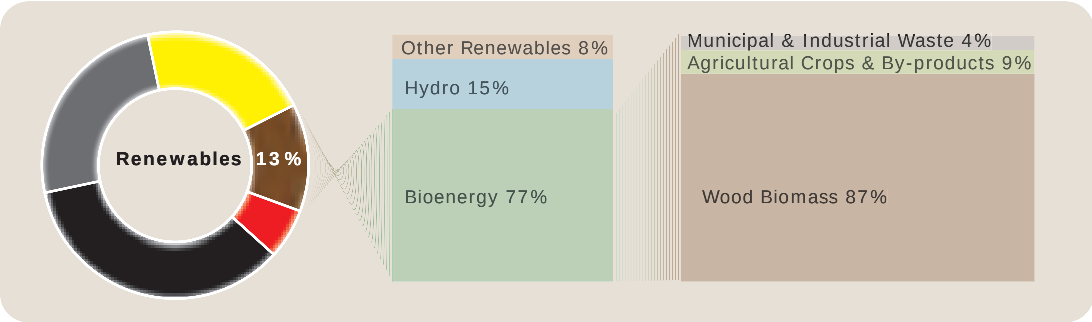
Biomass sources consist of 87 percent fuelwood and seven percent charcoal – the predominant energy sources for cooking in developing countries. Thus at least 50 percent of renewable energy sources worldwide derive from traditional energy cooking sources. Although it is debatable whether all of this biomass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

Figure 2. Shares of biomass



Source: Based on data from the IPCC, 2007

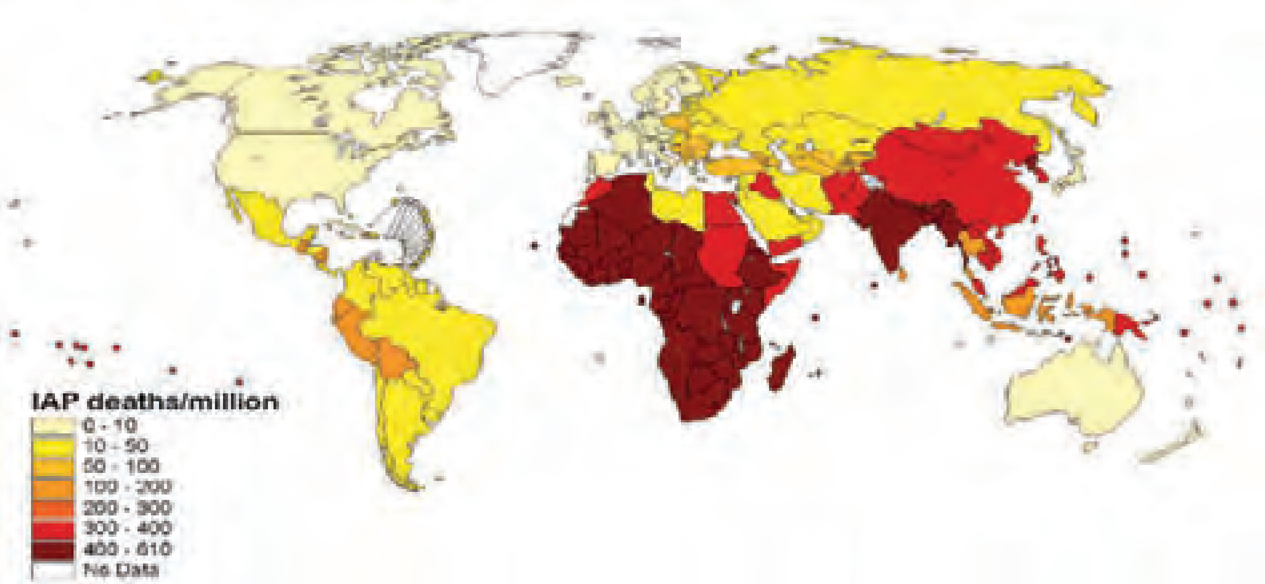
Figure 1. Primary energy sources in the world



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 CO2. 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)

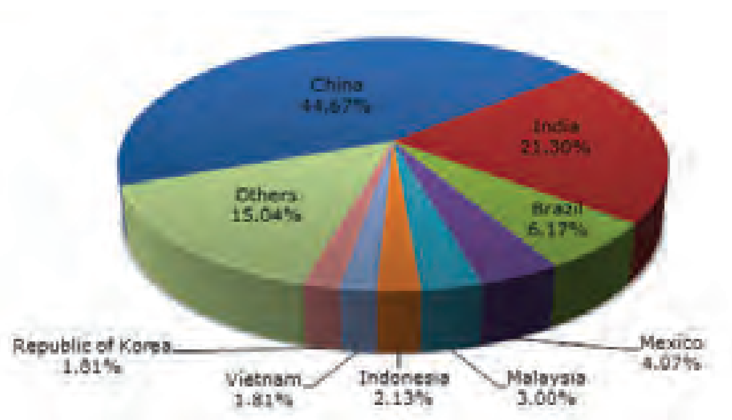
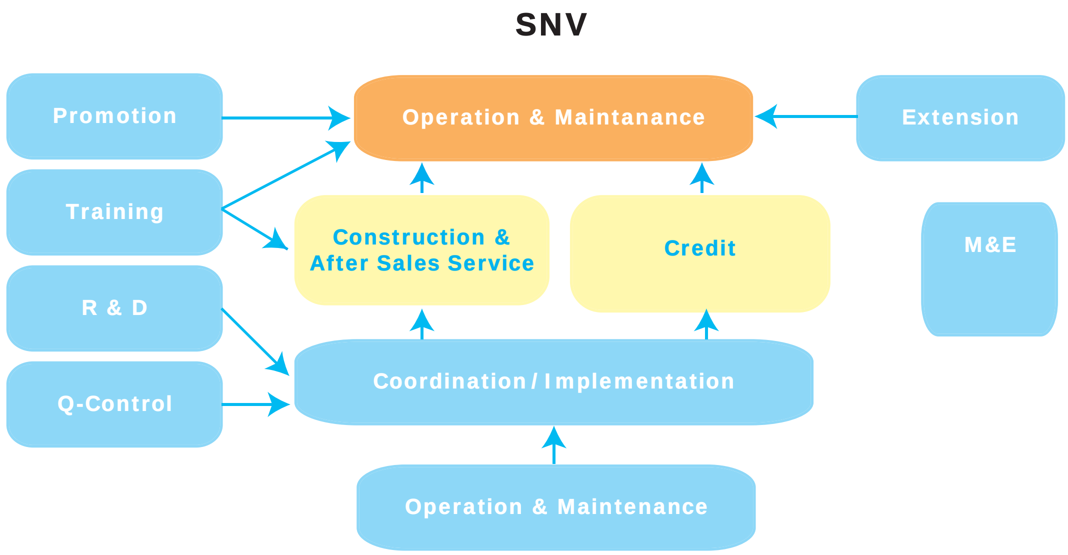


Figure 5. Functions required for National programmes on domestic biogas



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, 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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SECTION II: SUSTAINABLE BIOENERGY FEEDSTOCK PRODUCTION – EXAMPLES FROM THE REGION

Sweet sorghum - a better feedstock for bioenergy in Asia?

Shi-Zhong Li[1]

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.

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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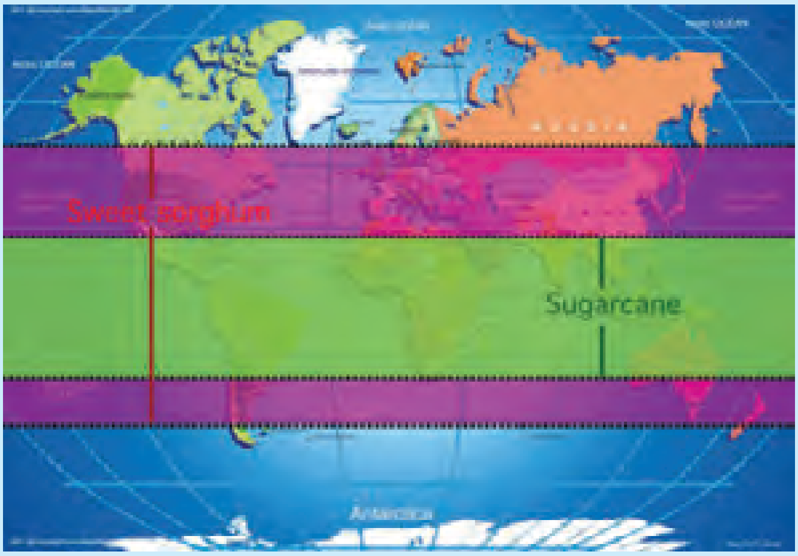
The advantages of sweet sorghum and the ASSF technology

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^3 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) Distiller pelletizing 193 kWh (GJ)	1.343 0.648 0.695	1.35 tonnes of pellets (GJ)	19.78
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		
Total (GJ)	18.203	**Total (GJ)**	49.08

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

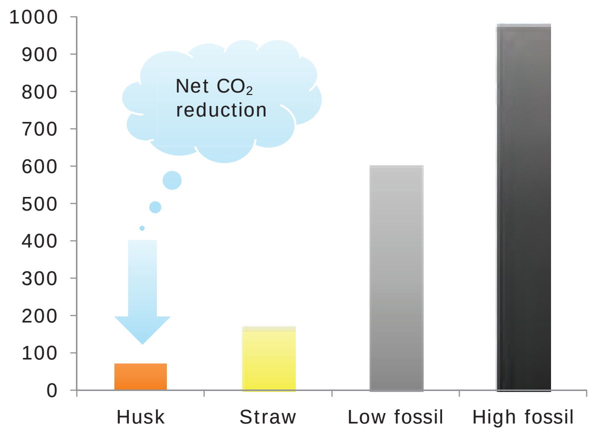
Werner Siemers[1]

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_2 released was accumulated by photosynthesis. If electricity, heat or fuels can be substituted, reductions of CO_2 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
Theoretical Potential				
Rice husk, Mta	38	6.5	6.1	30
Rice straw, Mta	200	21.5	22.0	100
Estimated Surplus				
Rice husk, Mta	See straw	1.0	1.6	10
Rice straw, Mta	37 to 150	6.0	11.0	22
Present Modern Use				
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[1]

Upali Amarasinghe[2], Beau Damen, N. Eriyagama[3], W. Soda[4] and V. Smakhtin[5]

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.

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.

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.

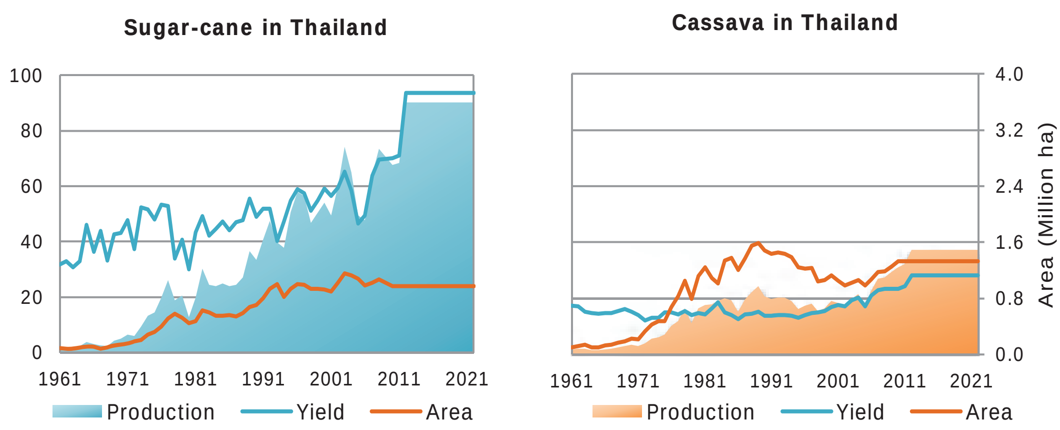
Using the water accounting framework developed by Molden (1997), an assessment was undertaken of

Table 1. Gasoline and diesel demand in Thailand

Gasoline demand in Thailand (MLPD)				
Year	Petroleum gasoline	Ethanol		Total
		Sugar-cane molasses	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)

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



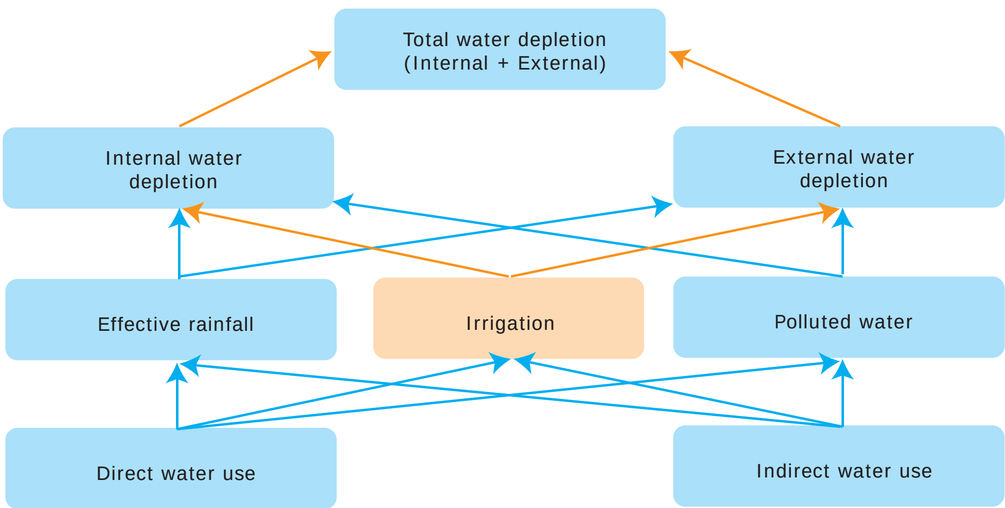
Sources: FAO (2010); DEDE (2010)

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 the Thailand, the potential to use the additional spent wash as fertilizer will be complicated by the Thai Government's policy not 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[1]

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.

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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