BIOMASS ENERGY — STATUS, OPPORTUNITIES AND CHALLENGES IN THE ASIA-PACIFIC REGION

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ABSTRACT

Bioenergy development in the Asia-Pacific region is faced with many challenges. Fuelwood and charcoal remain the dominant energy sources in the region. Many government and private sectors are becoming interested in expanding use of biofuel derived from agriculture and forestry biomass. Biofuels can contribute to climate change mitigation through substituting fossil fuels, when sustainably produced, and through carbon sequestration in forest and soils through afforestation and reforestation and improved land and forest management practices. The use of untapped residues and establishment of energy plantations can help prevent soil erosion and deforestation. Increasing use of biomass for energy could lead to improved economic development and poverty alleviation since it can generate employment and attract business opportunities from small- to medium-scale biofuel production. To assure a comprehensive sustainable bioenergy development, the synergic contribution of various institutions from the agriculture, forestry, energy, industry, and environment is important. These sectors, including the government, must examine and establish the economic viability of the technologies, the social opportunities and constraints to bioenergy development, its environmental impact at the local and global levels, potentials and limits to reduce greenhouse gas emissions, effects on biodiversity due to land use changes, and effects of feedstock production on water and soil. In a regional consultation conducted by FAO and other regional UN agencies, the three major areas identified as the focal concerns are: the need to address technical and economic issues related to bioenergy development; capacity development to promote, develop, and implement bioenergy programs; and installation of efficient political and institutional system and structure to support bioenergy programs. In building international framework on bioenergy, governments in the region may examine the experiences and results of existing global and international agreements.

Key words: biomass energy, biofuels, sustainable bioenergy development, Asia-Pacific region

STATUS OF BIOENERGY IN THE ASIA-PACIFIC REGION

Overall Energy Situation in the Region

The Asia-Pacific region had been experiencing the fastest economic growth in the world, led by China and India. Economic growth in many countries is leading to consumption patterns that approach those of industrialized countries. Growth is contributing significantly to increasing environmental pressure, with serious consequences for the environment, human health and long-term prosperity.

The region is home to over half the world’s population. It has two-thirds of the world’s poor, outnumbering Africa on this measure. Seven hundred and sixty-six million people in the region live on less than US$1 per day, 488 million in South Asia alone.2 Asia and the Pacific is a region of contrasts.

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1 This section is part of the FAO paper “Bioenergy: A Development Option for Agriculture and Forestry,” which the author was tasked to prepare. The paper was presented for discussion during the FAO 28th Regional Conference held on 15-19 May 2006 in Jakarta, Indonesia.

The main challenge facing the energy sector is how to continue to provide sustainable services for economic growth without jeopardizing long-term prosperity. In 2003, with a 59% share of the world’s population, the region’s share of the global Total Primary Energy Supply (TPES) was 41% and that of the global total electricity consumption was 36% (Table 1).

The increasing industrialization and current patterns of urbanization in the region point to a rapid increase in the long-term energy demand. Oil remains the key source powering the modern economic sectors of the region that include four of the world’s largest oil consumers – China, India, Japan, and the Republic of Korea. The region as a whole remains a large net oil importer, making it vulnerable to a sustained rise in oil prices. The region is also heavily reliant on domestic coal. China and India are the second and third world’s largest users after the USA. Some countries have more than 50% of their electricity generated from large hydropower plants. Small hydropower plants have also been developed to provide energy for local rural development. Solar and wind energy are rapidly commercializing in both developed and developing countries, with Japan leading the way, but their share in the total energy mix is not yet very significant.

Bioenergy, particularly woodfuels and agricultural residues, is the dominant energy source in many developing countries of the region. The region includes some of the countries with the highest consumption of wood and other bioenergy sources. Biomass is mainly used for cooking and space heating in households, but is also the main fuel for various heating applications in millions of small, medium and micro enterprises (SMMEs) found across the region.

The inefficient use of biomass, particularly in household cooking, is closely linked with health problems from indoor air pollution. Because of the drudgery and time intensive tasks related to the collection of fuelwood and the maintenance of fire, traditional biomass use is also closely linked to gender equity issues.

India and China have been at the forefront of modernizing bioenergy. These technologies include efficient use of biomass for large-scale industrial heating, power generation, and co-generation. There is also the commercialization of technologies such as improved charcoal production, biogas production, biofuels production, and gasification to make efficient, clean and convenient the use of biomass.

Table 1. Energy indicators of the Asia-Pacific Region, 2003

<table>
<thead>
<tr>
<th>Area</th>
<th>Population</th>
<th>GDP (PPP) 2000$</th>
<th>GDP (PPP) 2000$</th>
<th>Energy production</th>
<th>Net imports</th>
<th>TPES MTOE</th>
<th>Electricity consumption TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>OECD Asia-Pacific</td>
<td>199.6</td>
<td>5951.5</td>
<td>4934.4</td>
<td>388.3</td>
<td>617.8</td>
<td>852.4</td>
<td>1581.8</td>
</tr>
<tr>
<td>China</td>
<td>1295.0</td>
<td>1550.0</td>
<td>6265.0</td>
<td>1381.0</td>
<td>62.0</td>
<td>1426.0</td>
<td>1815.0</td>
</tr>
<tr>
<td>Central Asia</td>
<td>211.4</td>
<td>364.7</td>
<td>1467.5</td>
<td>1350.1</td>
<td>-96.2</td>
<td>779.1</td>
<td>943.6</td>
</tr>
<tr>
<td>Other Asia-Pacific</td>
<td>2018.0</td>
<td>1697.0</td>
<td>6371.0</td>
<td>1084.0</td>
<td>163.0</td>
<td>1224.0</td>
<td>1181.0</td>
</tr>
<tr>
<td>Asia-Pacific Region</td>
<td>3724.0</td>
<td>9563.2</td>
<td>19038.0</td>
<td>4203.3</td>
<td>746.6</td>
<td>4281.6</td>
<td>5521.4</td>
</tr>
<tr>
<td>World</td>
<td>6268.0</td>
<td>391.0</td>
<td>315.0</td>
<td>10709.0</td>
<td>-</td>
<td>579.0</td>
<td>15223.0</td>
</tr>
</tbody>
</table>

Source - IEA Key Statistics 2005

Wood Energy as the Dominant Bioenergy Supply

Woodfuel is the main bioenergy supply and its sustainable and efficient use was the concern of the FAO Regional Wood Energy Development Programme for the last 15 years. It has remained the dominant energy source in Cambodia, Lao People’s Democratic Republic, Nepal, Sri Lanka and Vietnam. Its significant role is expected to continue in the future. However, the inadequacy of wood energy statistics in most countries are constraints to a full understanding of the wood energy situation and outlook analyses.

In urban areas, the high cost of both fuel and stoves limits the use of kerosene or liquefied petroleum gas (LPG). Thus, opportunities for combining sustainable wood energy development with poverty alleviation programmes exist by legitimizing and improving existing informal woodfuel markets.

A significant number of rural and urban SMMEs, including some large-scale industries, are dependent on wood energy for process heating. SMMEs provide significant off-farm employment and income opportunities for rural people who make up the majority of the population in the region. Increases in woodfuel prices, due to possible woodfuel shortages if sustainable wood production is not assured, can threaten the economic viability of SMMEs. Unlike large industries, most SMMEs do not have the resources to switch to alternative fuels, or to improve woodfuel utilization.

The amount of fuelwood used by SMMEs, though smaller than the domestic sector, remains significant and could lead to local deforestation and degradation of non-forest lands (as non-forest areas are also significant woodfuel sources), making programs for sustainable production and efficient use of woodfuels by SMMEs necessary.

Many woodfuel users are in agricultural areas far from forests. They collect woodfuels from trees on farms and grazing lands, small woodlots, home gardens, and trees grown along roads, rivers and canals. Changes in land use, especially conversion of forests into other land uses such as crop production, also generates woodfuels as by-products. An FAO report shows an indication of the importance of woodfuels coming from non-forest areas (Table 2).

Future Wood Energy Scenarios

Interrelated factors influence woodfuel demand, making wood energy outlook studies an arduous task that is compounded by the inadequacy of data. The factors are site-specific, thus site-specific analyses of wood energy are desirable if data are available. Still, another FAO study analyzes three possible broad scenarios for wood energy in the region:

The first is a business-as-usual (BAU) scenario that excludes any policy intervention either to increase fuelwood supply or to reduce or increase fuelwood demand. In this scenario, woodfuels demand is based on past and present patterns of growth of consumption (Table 3). Unsustainable patterns of wood energy consumption are projected to continue exacerbating the current situation. Even areas where the supply and demand for woodfuels is balanced, could move to unsustainable situations.

The second scenario, called the energy (GREEN) scenario, assumes greater future fuelwood

| Table 2. Estimates of woodfuels from non-forest areas in country reports |
|-----------------|---------------------|---------------------|
| Countries       | Million mt | % Share of total supply | Sources                                                                 |
| India           | 62.0       | 36                    | Shrubs from degraded lands/ roadsides, twigs/branches from homestead gardens |
| Nepal           | 2.3        | 36                    | Shrub lands, grasslands, non-cultivated inclusions, cultivated lands        |
| Philippines     | 70         | 82                    | Farmlands, brush lands, grasslands, trees in coconut plantations            |
| Sri Lanka       | no data    | 88                    | Home gardens, croplands, coconut / rubber wood plantations, processing residues – data is for biofuels |
| Thailand        | 19.7       | 42                    | Agroforestry, tree crops, other croplands, other lands                     |
| Viet Nam        | 13.9       | 74                    | Perennial crops, bare lands, scattered trees, forest industry, recovered wood |

consumption than that projected in the business-as-usual case. Under this scenario, woodfuel consumption would increase owing to deliberate efforts to promote efficient use and sustainable production of woodfuels resulting in environmental benefits. This green scenario presents itself as the most desirable one. Achievement of such scenarios will be dependent on adhering to “key success factors” in the planning and implementation of programs.

The third or "massive" fossil fuel promotion (FOSSIL) scenario appears unlikely to be adopted owing to the significant rise in the price of petroleum fuels and concern over the increase in greenhouse gas emissions from the use of fossil fuels.

Modernizing Bioenergy Systems

Modern bioenergy development has focused on biopower systems. In the last two years, there has been rapid growth in liquid biofuel production and use.

- Biopower – Biomass-fuelled power generation or “biopower” is the second most developed renewable energy-based power system after hydropower in the region. Applications include decentralized and grid-connected biopower plants. In the last decade, cogeneration systems employing advanced biomass direct combustion technologies utilizing agricultural wastes to simultaneously produce heat and power have been successfully commercialized in the region.

- Improved Biomass Heating Technologies – Improving heating technologies remain important in modernizing bioenergy. These include stoves, kilns, ovens and furnaces for cooking and space heating in households and institutions, and process heating in SMMEs. Biomass will continue to be their main fuel for the foreseeable future. Improving and modernizing heating technologies should be complemented by sustainable biomass production programs.

- Gasifiers – Gasifier technology for thermal and electricity generation applications using agricultural residue has made a comeback in the region since 2001. Chinese and Indian companies are pioneering its commercialization. Sri Lanka established pilot-commercial “dendrothermal systems” (integrated tree plantations – gasifier-based power plants) for both off-grid and grid-connected operations using gliricidia trees intercropped with coconut and tea. This concept is also being started in Bangladesh, Cambodia, Myanmar, Nepal, Thailand and Viet Nam.

- Biogas – China’s success in biogas technology has long been recognized. Over the past five years, the Nepal Biogas Support Programme (BSP) has been successful in commercializing biogas technology. More than 123,000 biogas units have now been installed. Households also acquire herds of cattle that provide additional income to pay back loans for the biogas system.

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In addition, effluents from the biogas digesters rich in nutrients are applied in farms to increase harvests. The BSP is implemented jointly with rural-based micro lending facilities. Fifty private biogas companies emerged that not only sell, manufacture and install the systems, but also provide after-sales support, maintenance and repair services. Bangladesh and Bhutan are planning a similar programme.

- Liquid Biofuels – The rapid growth of the transport sector in the region coupled with stiff increases in oil prices are hastening commercialization of liquid biofuels, particularly alcohols and biodiesel. Trade in biofuels is an emerging concern among countries. Japan is supporting biofuel development in the region.

**COST COMPETITIVENESS OF BIOENERGY TECHNOLOGIES**

Modern Sustainable Biomass Heating

The most common interventions in biomass heating is the introduction of improved fuelwood and/or biomass stoves and other improved biomass-fuelled heating devices (furnaces, kilns and boilers) coupled with activities to ensure the sustainable production of biomass.

In recent years, modernizing biomass heating, through the use of gasifiers, has become competitive both with improved biomass direct combustion devices and fossil-fuel heating technologies (Fig. 1). Gasifiers generate producer gas, a low-BTU gaseous fuel. The use of gasifiers complements strategies for sustainable biomass resource production. Gasifiers can use agricultural wastes briquettes and small pieces of wood (in the form of cut twigs and branches) and still generate high-temperature combustion. Use of small pieces of wood allows for sustainable harvesting by lopping only branches and twigs of farm trees, assuring sustainable biomass production.

Biogas for cooking and heating is another form of renewable energy intervention for improving supply of biomass energy for heating. China and Nepal have been the most successful countries in this area. In both countries, biogas technology has been developed to commercial stage. The number of biogas users continued to increase in China, India, and Nepal. China reported 17 million existing biogas users in 2005, up from previous reports of 12 million. Biogas remains a priority in India, with about 3.8 million household-scale biogas plants now reported installed, up from prior reports of 3.7 million, and 66,000 new plants were expected to be installed from early April 2005.

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Fig. 1. Comparative energy cost of producer gas with other fuels for heating, India, 2004.

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to April 2006. Nepal was providing 75% subsidies for family-scale biogas plants\(^\text{12}\).

**Competitiveness for Off-grid and Mini-grid Electrification**

Based on the most recent and comprehensive comparative techno-economic assessment of renewable energy-based (including several modern biomass energy technologies mentioned previously) and fossil-based power generation technologies (a 2005 study undertaken jointly by energy research institutions and power generating companies under the direction of the World Bank), renewable energy technologies for off-grid and mini-grid applications are competitive with gasoline and diesel gensets\(^\text{13}\).

- Renewable energy, among them bioenergy technologies, is more economical than conventional generating for off-grid (less than 5 kW) applications. Renewable energy technologies (e.g. wind, mini-hydro, and biomass-electric) are the least-cost option (on a levelized basis) for off-grid electrification applications, assuming availability of the renewable resource. Pico-hydro, small wind, and PV-wind hybrid technologies in particular are projected to be in the range 15-25 cents/kWh, less than half the 30-40 cents/kWh for gasoline and diesel engine generators. The most expensive renewable energy technology (solar PV) is comparable in levelized electricity costs to the projected costs for gasoline or diesel engine generators, especially for small power applications (50-300 W) (Fig. 2).

- Several renewable energy technologies, again including bioenergy technologies, are potentially the least-cost option for mini-grid applications. Mini-grid applications are village- and district-level networks with loads between 5 kW and 500 kW not connected to a national grid. The assessment indicates that numerous renewable energy technologies (biomass, biogas, geothermal, wind, and micro-hydro) are the potential least-cost generating option for mini-grids, assuming a sufficient renewable energy resource is available. Two biomass technologies (biogas digesters and biomass gasifiers) seem particularly promising, due to their high capacity factors and availability in size ranges matched to mini-grid loads. Geothermal also appears economical, recognizing that it is restricted to only those developing economies with easy-to-tap hydrothermal resources and no large field development costs. Since so many renewable energy sources are viable in this size range, mini-grid planners should thoroughly review their options to make the best selection. (Fig. 3).

**Competitiveness of Biofuels**

Even with subsidies, the economic savings with biofuels from avoided oil imports can be considerable: between 1975 and 1987, ethanol saved Brazil $10.4 billion in foreign exchange while costing the government $9 billion in subsidies. This investment paid off even more in subsequent years: studies show that from 1976–2004, Brazil’s ethanol production substituted for oil imports worth $60.7 billion — or as much as $121.3 billion including the avoided interest that would have been paid on foreign debt (based on debt previously incurred importing oil)\(^\text{14}\).

The World Bank reports that biofuel industries require about 100 times more workers per unit of energy produced than the fossil fuel industry. The ethanol industry is credited with providing more than 200,000 jobs in the United States and half a million direct jobs in Brazil\(^\text{15}\).

The technologies to produce ethanol from sugarcane and grains and biodiesel from oil seeds are mature with cost structures that are fairly well understood. Incremental improvement is continuing, but major technical breakthroughs under current processes are not expected. Thus, future costs are likely to be similar to the costs of production observed today.

The cost of ethanol production in Brazil at the exchange rate prevailing in mid-2005 is in the neighborhood of US$0.25 per liter, the lowest in the world. Much lower figures have been reported in the past. The rise in the cost of ethanol production is primarily as a result of depreciation of the U.S. dollar against the Real, and does not mean that the ethanol industry in Brazil has become less competitive. A study of a biodiesel plant based on Jatropha in India yielded a biodiesel cost of US$0.40 per liter if by-product sale credits of US$0.08 per

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\(^\text{15}\) Ibid
Fig. 2. Electricity generation costs — off-grid technologies, 2004 & 2015.
Fig. 3. Mini-grid generation costs, 2004 & 2015.
liter of biodiesel for glycerine and US$0.05 per liter for animal seed cake can be assumed. If by-product prices fall markedly as a result of oversupply, then the ex-factory price of biodiesel could be as high as US$0.53 per liter\textsuperscript{16}.

A review of biofuel production costs in 2002 gave the estimates for various biofuels shown in Table 4 (AEA Technology 2003). The cost of ethanol production varies from the low of US$0.19 per liter in Brazil to the high of US$0.51 per liter from beet sugar in the European Union. The cost of ethanol production from maize in the United States in this study is even lower than the optimistic projections given by the U.S. ethanol industry. The cost of biodiesel production is much higher, and without dramatic cost reductions in the foreseeable future, the price of crude will need to increase further from the level in mid-2005 (about US$35/barrel) before biodiesel can compete with petroleum diesel\textsuperscript{17}.

**Status Report of Global Bioenergy Utilization\textsuperscript{18}\**

Based on the Renewable Energy 2007 Global Status Report, in 2006, renewable energy supplies 18\% of the world’s final energy consumption, counting traditional biomass, large hydropower, and “new” renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) (Fig. 4). Traditional biomass, primarily for cooking and heating, represents about 13\% and is growing slowly or even declining in some regions as biomass is used more efficiently or replaced by more modern energy forms (Fig. 5).

Biofuels for transport make small but growing contributions in some countries and a very large contribution in Brazil, where ethanol from sugar cane displaces over 40\% of the country’s gasoline consumption. In developing countries, over 300 million households use traditional biomass for cooking and heating; 25 million households cook and light their homes with biogas (displacing kerosene and other cooking fuel); and a growing number of small industries, including agricultural processing, obtain process heat and motive power from small-scale biogas digesters. Biofuels also grew rapidly during the period, at a 40\% annual average for biodiesel and 15\% for ethanol.

**CHALLENGES TO BIOENERGY DEVELOPMENT**

In developing countries of Asia and the Pacific region, fuelwood and charcoal remain the dominant energy sources. However, wood energy is becoming an increasingly important industrial energy option in many developed countries including those in the region such as Australia and Japan, as it is locally available and environmentally friendly.

Liquid biofuels have gained importance in the last decades in Brazil and more recently in Europe, Japan, the United States of America, and other Organisation for Economic Co-operation Development (OECD) countries, particularly in the transport sector, with the role of agriculture gaining in importance. Many agro-industries, such as sugar mills, already generate process heat and electricity from bagasse, thus becoming energy self-sufficient. Some are also ethanol producers and electricity providers to the grid. The bioenergy potential of other agro-industries processing rapeseed, castor oil, palm oil, bananas, rice, wheat, sorghum, cassava and many other crops is considerable. Technologies for producing synthetic fuels from biomass and their applications in fuel cells are triggering interest in the use of energy crops as rotating crops in conservation agriculture.

There is growing interest on the part of many governments and the private sector in expanding the use of biofuels derived from agricultural and forestry biomass.

Biomass is a locally available energy source that can produce heat and power based on liquid, gas or solid derived fuels, which can contribute to the substitution of imported fossil fuels, thus enhancing national energy security as well as the diversification of energy sources.

As a carbon-neutral source of energy, biofuels can also contribute to climate change mitigation through substituting fossil fuels, when sustainably produced, and through carbon sequestration in forest and soils through afforestation and reforestation activities and improved land and forest management practices. Nevertheless, the ability of bioenergy to reduce greenhouse gas emissions varies depending on the forms of biomass production, conversion and utilization and, in some instances, may even prove negative in net energy value.


\textsuperscript{17} Ibid

Table 4. Biofuel cost in 2002 in US$ per liter (WB-ESMAP 2005)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Feedstock</th>
<th>Location</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiesel</td>
<td>Oil seeds</td>
<td>US</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Oil seeds</td>
<td>EU</td>
<td>0.62</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Sugarcane</td>
<td>Brazil</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>Maize</td>
<td>US</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>EU</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Sugar beet</td>
<td>EU</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>Straw - acid hydrolysis</td>
<td>EU</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>Wood - acid hydrolysis</td>
<td>US</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Note: Original costs in Pound Sterling converted to US$ using the average exchange rate for calendar 2002.

Fig. 4. Renewable energy share in global energy consumption, 2006.

Fig. 5. Average annual growth rates of renewable energy capacity, 2002–2006.
The utilization of untapped residues and the establishment of energy plantations can address other important environmental concerns. Energy crops (in particular perennial crops) can help prevent soil erosion by providing a cover which reduces rainfall impact and sediment transport. Annual energy crops can also allow diversification and expansion of crop rotations. Deforested, degraded and marginal lands could be rehabilitated as bioenergy plantations which could combat desertification and increase food production. With increased utilization of biomass for energy production, crop residues will have an economic value.

Increasing the use of biomass for energy could also lead to improved economic development and poverty alleviation, especially in rural areas, since it attracts investment in new business opportunities for small- and medium-sized enterprises in biofuel production, preparation, transportation, trade and use, and generates incomes (and jobs) for people in and around these areas.

In many countries, biofuels can be produced in large quantities when they are derived from forest, agro-industrial and mill residues and increasingly from agricultural crops. Decreasing the price difference between fossil fuels and biofuels remains a major constraint when these prices are based on direct cost analysis, even when the recent volatility in international oil prices is making bioenergy more attractive. However, the benefits of bioenergy, if properly internalized, can offset the price difference with fossil fuels. The Clean Development Mechanism (CDM) of the Kyoto Protocol offers additional incentives for establishing energy plantations and opportunities for technology transfer.

Research and development work is leading to reduced production costs, higher energy conversion efficiency and greater cost-effectiveness of bioenergy. For instance, research will provide new opportunities to utilize a wider range of lignocellulosic biomass from timber mills, agro-industries and urban waste, as well as traditional agricultural and forest residues. Innovation in bioenergy will allow developing countries to leapfrog to modern technologies.

Bioenergy systems are relatively complex, interdisciplinary, intersectoral and site-specific. Therefore, solving problems is challenging and requires the integration of biofuel production into conventional agricultural and forestry activities as well as the synergic contribution of various institutions from the agriculture, forestry, energy, industry and environmental sectors.

Bioenergy, Food Security and Sustainability

To develop the full potential of bioenergy, growth has to be managed in sustainably to meet requirements related to the economic, social and environmental dimensions of sustainability. Much progress has been achieved in the local and global debate on criteria and mechanisms to achieve sustainability in various fields and for different products, particularly through multi-stakeholders and producer-consumer partnerships. The emerging biofuel market should build upon these lessons. In the recently “High Level Conference on World Food Security: The Challenges of Climate Change and Biodiversity” organized by FAO in Rome, Italy last 3-5 June 2008, the conference identified the following as the key points to be addressed to assure a comprehensive sustainable bioenergy development19.

Economic dimension. In theory, bioenergy is economically sustainable if it is financially viable after all direct and indirect impacts – both positive and negative – have been accounted for. Policies can promote economic sustainability of bioenergy by rewarding those technologies and systems that perform well in terms of social and environmental impacts, for instance net greenhouse gas (GHG) reduction. By stimulating innovation and improving productivity over time, performance-based policies can promote dynamic efficiency. This is essential if the sector is to remain economically sustainable over time and bring economic opportunities to those who depend on the agricultural sector. Barriers to international trade constrain economic sustainability by hindering the exploitation of the most efficient production paths.

The economic dimension is critically linked to the scale and method of production, and the use of and impacts on human and natural resources discussed below.

Social dimension. Impact on food security is one of the core social factors to be considered in bioenergy development. Other factors include opportunities for pro-poor rural development, income generation through productive activities or employment, land access and labor conditions.

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The growing market for biofuels presents new income opportunities for agricultural producers, including smallholders. However, benefit distribution at household level may not be equal, with evidence suggesting that increased cash returns to farming disproportionately benefit male household members. The social impacts of biofuel development will depend upon the feedstock and the production system chosen. If economically viable, small-scale cultivation of crops such as jatropha and on-farm or community-level use of crude vegetable oil can revitalize rural economies by improving mechanization, irrigation and transport and decentralizing energy supply. In addition, biofuel production provides by-products and co-products such as glycerine, livestock feeds and fertilizers.

However, comparative experiences indicate that production of some biofuels, in particular ethanol, is more competitive if it relies on economies of scale related to large-scale industrial production. This is due to the high investment cost related to processing. While the employment generation potential, particularly for unskilled labor, may be significant, preliminary evidence hints at a rapid pace of mechanization and simultaneously a decrease of manual workforce. In addition, labor rights and socio-economic conditions in large-scale biofuel plantations can be precarious. Female workers tend to be particularly disadvantaged. Large-scale development also puts pressure on land.

Increasing land value may strengthen the asset base of landholders, but make lease or purchase of land unaffordable for the landless. In situations of insecure land tenure, large-scale developments may lead to displacement of vulnerable households with indigenous communities particularly at risk.

Small-scale and large-scale production systems must not be mutually exclusive. Governments can promote the adoption of contract farming in which the processor purchases the harvests of independent (smallholder) farmers under terms agreed to in advance through contracts. Further, assisting smallholders in building cooperatives, marketing associations, partnerships and joint ventures, and coordinating their supply into larger production facilities will benefit smallholder participation in biofuel markets just as it holds potential for other agricultural markets.

**Environmental dimension.** Bioenergy production affects the environment at the local and global levels, impacting land and water resources, biodiversity and the global climate. Although there are environmental impacts throughout the production chain – feedstock production, conversion and use – most impacts occur in the feedstock production stage and mirror those related to agricultural production in general.

**Climate change mitigation.** Mitigation of climate change is a policy goal of bioenergy development in many countries. However, life-cycle analyses that measure emissions throughout the bioenergy production chain indicate a wide divergence in carbon balances according to technologies used, locations and production paths – with some even leading to greater emissions than fossil fuels. Key sources of emissions are land conversion, mechanization and fertilizer use at the feedstock production stage, and the use of non-renewable energy in processing and transport. Systems that use organic waste and residues from agriculture and forestry, or perennial energy plants on degraded land, offer high potential greenhouse gas (GHG) emissions savings. The impact of landuse change, an aspect of particular importance in the carbon balance, remains clouded in uncertainty. When land with high carbon content, such as forest or peat land, is converted to grow biofuels, the immediate resulting carbon balance is inevitably negative, with conversion creating “carbon debts” that could take decades or even centuries to “repay”.

In addition, a comprehensive carbon balance assessment must take into account “indirect” land-use change, which refers to emissions from land in which biofuel feedstock replaces food crops. Such indirect effects are notoriously difficult to attribute and measure. The extent of land-use change caused by bioenergy growth depends upon the potential for intensification. Some further yield improvements on existing land will be possible in response to rising prices, in particular through increased input use and improved management practices. However, improved bioenergy feedstock technologies are still in the development stage so, in the short run, the lion’s share of increased production is likely to come from area expansion. The faster the growth in the market, the greater the likely negative impact on land-use.

**Biodiversity.** The threat to wild biodiversity from bioenergy growth is associated primarily with land-use change. When areas such as natural forests are converted for feedstock production, the loss of biodiversity may be significant, even if land expansion is a temporary phenomenon. A further
concern is the introduction of invasive species for biofuel production. Agricultural biodiversity could be affected by large-scale monocropping practices and the introduction of genetically modified materials.

**Water and soil.** Many feedstocks – including sugar, palm oil and maize – are highly water intensive, meaning that their expansion is likely to create even greater competition for this already scarce resource, depending upon location and production methods. Liquid biofuels already account for approximately 1% of water transpired by crops and 2% of irrigation water. Feedstock production also affects downstream water quality through run off of fertilizers and agrochemicals, and soil erosion. The impact of feedstock production on soil erosion depends critically on the farming techniques that are employed, in particular on the use of tillage practices, the level of soil cover and crop rotations. Where perennial bioenergy feedstocks replace annual crops, the permanent cover and root formation will help improve soil management and reduce soil erosion.

The adoption of good agricultural practices, such as no tillage and direct seeding, retention of soil cover, multiple cropping, appropriate crop choice and crop rotations, can mitigate negative impacts, in particular on carbon, soil and water resources. The application of these practices also can reduce the threat to biodiversity, particularly soil biodiversity, through the retention of crop residues and diversified crop rotations.

Wildlife habitats can be enhanced by introducing landscape approaches in agricultural areas and retaining ecological corridors, as well as by careful and sustainable use of high biodiversity biomass sources, such as grasslands, as feedstocks. Furthermore, non-food cropping systems could enrich agrobiodiversity. Promoting integrated local food-energy production systems, by combining feedstock production with crop production and feeding livestock on biomass not used for energy production or soil cover, can avoid waste and increase the overall system productivity for food and energy.

**Planning and Programming Concerns for Bioenergy Development**

In many regional consultations conducted by FAO and other regional UN agencies promoting sustainable bioenergy development, three major areas have been identified that require particular attention from the agriculture, forestry and rural development sectors of Asia and the Pacific region to mobilize the full potential of bioenergy, assure sustainability in terms of the economics of the projects and in terms of social and environmental benefits:

**Technical and economic issues:**
- Lack of data on the quantity, quality and potential of bioenergy sources and technologies;
- Poor understanding of the energy balances of bioenergy production systems and of their potential and limits to reduce greenhouse gas emissions;
- Lack of understanding of the mechanisms to draw economic benefits from the positive environmental effects derived from bioenergy production;
- Poor understanding of the interrelations between wood and agro-energy systems;
- Insufficient information about costs, advantages/disadvantages of using wood and agrofuels;
- Lack of regulations to ensure that biofuels are produced, traded and used according to appropriate guidelines and standards; and
- Lack of equipment and poor knowledge of the appropriate practices for harvesting, transportation, storage and use of biofuels.

**Capacities:**
- Insufficient capacities to promote, develop and implement bioenergy at national, regional and international levels;
- Weak channels of communication between public and private stakeholders;
- Lack of human resources trained in bioenergy;
- Insufficient attention to bioenergy in forestry/agriculture/energy/engineering curricula;
- Inadequate educational and technical materials;
- Insufficient tools, methods and models for project development, evaluation and monitoring, particularly regarding bioenergy supply; and
- Weak information and statistical data on resources, production, trade and consumption of biomass for energy purposes.

**Policies and institutions:**
- Inadequate understanding of the energy implications of the MDGs;
• Fragmentation of responsibilities and lack of coordination among institutions;
• Insufficient communication, cooperation and participation of these institutions and private stakeholders such as forest owners, farmers, communities, agro-industries and NGOs;
• Lack of agriculture, forestry and energy policies and cross-sectoral approaches to promote the integration and diversification opportunities of bioenergy activities;
• Inadequate legislation and lack of energy incentives in most countries, such as preferential tax treatments;
• Insufficient support to the private sector, forest owners and farmers on biofuel production; and
• Potential overlap in mandates, roles and functions of international organizations.

Building International Framework on Bioenergy

Both governments and the private sector have requested that FAO assist in establishing a consensus on bioenergy, particularly liquid biofuels. This interest became evident in the preparatory process for the 2008 High-Level Conference. Although there is no formal international agreement or intergovernmental mechanism to deal with bioenergy or biofuels, several existing treaties and initiatives that touch upon issues related to food security, energy, environment, trade and human rights are relevant to bioenergy. Throughout the past decades, bioenergy and other renewable energies have been the subject of several international meetings, declarations and commitments on sustainable development. In building international consensus on sustainable and food security-compliant biofuels, governments may wish to integrate elements or draw from the experiences of the following existing agreements:

• UN Conference on New and Renewable Sources of Energy (NRSE), in 1981, where the Nairobi Plan of Action was adopted.
• UN Conference on Environment and Development: in Agenda 21, emphasis was given to the role of bioenergy in the Chapters dealing with Protection of the atmosphere; Combating deforestation; and Promoting sustainable agriculture and rural development.
• UN Millennium Declaration: while there is no energy-related goal in the MDGs, most of these have a direct energy implication. In fact, a recent publication by UN-Energy assesses these implications. (see: http://esa.un.org/un-energy/).
• World Summit on Sustainable Development (WSSD) – energy was high on the agenda; the WEHAB concept focuses on five key thematic areas: Water, Energy, Health, Agriculture and Biodiversity. In the Johannesburg Declaration, energy was considered a human need on a par with other basic human needs (clean water, sanitation, shelter, health care, food security and biodiversity); bioenergy was highlighted in various Chapters of the adopted Plan of Implementation.
• The International Conference for Renewable Energies held in Bonn in June 2004 was the largest gathering ever on this topic. Bioenergy was highlighted as one of the most promising energy sources of the future.
• Other important initiatives include the Global Environmental Facility (GEF); the G-8 Task Force on Renewable Energy; the UNDP Initiative on Energy for Sustainable Development; and specific programmes aimed at supporting renewable energy by multilateral institutions such as the World Bank, the Inter-American Development Bank and other agencies.
• FAO’s International Bioenergy Programme is in the process of implementation. The Government of Italy has launched the Global Bioenergy Partnership.

LIST OF FOOTNOTES

6 Ibid.
Lanka (Biomass Energy Association of Sri Lanka, TERI-India, NRI-UK, CTI-Italy).


15 Ibid.


17 Ibid.
