

Forests and energy in developing countries



FORESTS AND ENERGY WORKING PAPER 2

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Contents

SUMMARY	v
GLOSSARY OF TERMS	vi
ACRONYMS	vii
1. INTRODUCTION	1
2. ENERGY THROUGHOUT THE WORLD	3
Importance of the energy sector	3
Global demand for energy	4
Renewable energy sources and biomass	6
3. BIOENERGY IN DEVELOPING COUNTRIES	9
Traditional uses	9
Recent developments in bioenergy	12
Policies and programmes to promote bioenergy	13
4. COMPETITION FOR LAND AND FOOD SECURITY	19
5. FORESTS AND BIOENERGY	21
Opportunities for developing countries	21
Threats and implications	25
6. CONCLUSIONS AND RECOMMENDATIONS	29
REFERENCES	31

Summary

The energy sector plays a vital role in the world economy. Increased fossil fuel prices, energy security issues and climate change have been the main driving forces to development of alternative and renewable energy sources. As a result of increased population expansion and faster economic growth, energy consumption is growing rapidly in non-Organisation for Economic Co-operation and Development (OECD) countries, particularly China and India.

In spite of national and international efforts, however, most energy in the future will continue to be based on fossil fuels. Renewable energy currently accounts for 7 percent of global energy consumption, and is largely based on hydropower and biomass. Most biomass energy is consumed in developing countries (70 percent of the total), mainly for cooking and heating, with a smaller share going to power generation.

Traditional biomass for energy includes fuelwood, charcoal, manure and crop residues. These are important sources of energy for many developing countries, and provide the bulk of energy supply for many dispersed and poor rural populations around the world. Wood is by far the most important biomass type; total annual wood removals are 3.3 billion m³, more than half of which is used for energy.

In recent years, several countries have developed policies and programmes to promote the use of renewable energy sources, and bioenergy has received particular attention. In preparing this paper, the policies and programmes of selected developing countries were reviewed, and in most cases it was found that the main focus is on liquid fuels (ethanol and biodiesel), with little reference to traditional forest-based bioenergy.

In general, the policies and programmes of developing countries are also relatively limited in scope, focusing mainly on regulatory measures, with little attention to other relevant aspects such as research and development (R&D), market liberalization, information campaigns and training. Furthermore, it was observed that most countries have set ambitious targets that are unlikely to be met, because implementation of the programmes is still at an early stage.

In developing countries with abundant forest resources, priority should be given to opportunities for producing energy based on established forest operations and proven technology. New opportunities, such as energy crop projects and the development of new technologies, should be left for a second stage.

Energy crops can affect food security and the wood processing industry, but there are ways to combine land uses and mitigate impacts. In many developing countries, extensive degraded lands are available, and planting trees in these areas is an option for reducing erosion and restoring ecosystems.

The use of residues and by-products, particularly in the wood processing industry, is another way of creating a win-win situation for forest industry and energy production, without affecting biodiversity and food security. It is also important to assess the risks associated with projects and investments in bioenergy, as in many cases the feasibility of biofuel production still depends on subsidies and new technology developments.

Glossary of terms

Bioenergy

Energy obtained from biomass: fuelwood, charcoal, sugar cane bagasse, maize, livestock manure, biogas, algae, etc.

Traditional bioenergy: Unrefined fuels such as fuelwood, charcoal, crop and animal residues, used mainly for cooking and heating.

Biofuel

A feedstock intended for the production of bioenergy. It may be solid, such as fuelwood, wood pellets and charcoal, or liquid, such as biodiesel and bioethanol.

Biomass

Material of biological origin, excluding that embedded in geological formations and transformed into fossil.

Black liquor

An alkaline-spent liquor obtained from digesters in the production of sulphate or soda pulp during paper production. The energy content is mainly derived from lignin removed from the wood in the pulping process.

Firewood

Cut and split, oven-ready fuelwood used in household wood-burning appliances such as stoves, fireplaces and central heating systems. Firewood is usually of uniform length, typically in the range of 150 to 500 mm.

Fuelwood

Woodfuel in which the original composition of the wood is preserved.

GHGs

Greenhouse gases: those covered by the Kyoto Protocol are CO₂, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

Kyoto Protocol

The international agreement to address the threat posed by the steady accumulation of heat-trapping GHGs in the earth's atmosphere.

Renewable energy

Energy that is produced and/or derived from sources that can be renovated, such as hydro, solar and wind energy, or generated from combustible renewables, such as sustainably produced biomass. Renewable energy is usually expressed in terms of energy units; for fuels, these are based on net calorific values.

Wood energy

The energy derived from woodfuel. It corresponds to the net calorific value of the fuel.

Woodfuels

All types of biofuel originating directly or indirectly from woody biomass.

Acronyms

CDM	Clean Development Mechanism (Kyoto Protocol)
CIS	Commonwealth of Independent States
CO₂	carbon dioxide
EIA	Energy Information Administration (United States)
EU	European Union
GDP	gross domestic product
GHG	greenhouse gas
IADB	Inter-American Development Bank
IEA	International Energy Agency
ITTO	International Tropical Timber Organization
LKS	less-known species
LUS	less-used species
MJ	megajoules
MME	Ministry of Mines and Energy (Brazil)
Mtoe	metric tonne oil equivalent
NAS	National Academy of Sciences
NGO	non-governmental organization
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
PNPB	National Programme for the Production and Use of Biodiesel (Brazil)
R&D	research and development
SFL	Biofuels Law (Argentina)
SMEs	small and medium-sized enterprises
UNFCCC	United Nations Framework Convention on Climate Change
VAT	value-added tax
WEC	World Energy Council
WHO	World Health Organization
WTO	World Trade Organization

1. Introduction

Energy plays an important role in the world economy; changes in energy costs affect global economic growth, especially in oil importing developing countries. Fuels represent about 11 percent of all international trade, and almost 50 percent of that in primary products. In some countries, fuel exports account for 80 percent or more of total exports.

The importance of energy goes beyond the monetary values of energy transactions, however. There are also strategic issues, such as energy security, which have always been an important component of national and international discussions, and which drive political decisions.

A substantial share of global energy derives from oil, and oil prices have recently reached high levels, with effects on the prices of other energy sources. A general increase in energy prices, together with a projected shortage of fossil fuels in the future and concerns about climate change, are increasing the pressure on countries to find new alternatives for energy supply, especially alternatives based on renewable sources, including bioenergy.

Bioenergy can be defined as energy obtained from biological and renewable sources (biomass), normally in the form of purpose-grown energy crops or by-products from agriculture, forestry or fisheries. Examples of bioenergy resources are fuelwood, charcoal, sugar cane bagasse, maize, sweet sorghum stocks, livestock manure, biogas, microbial biomass and algae.

Wood is one of the main sources of energy and has been used for energy since the Stone Age. Many countries have large forested areas, which if sustainably managed can produce large quantities of carbon-neutral and renewable fuels, replacing a significant portion of fossil fuels. A number of countries already have policies in place to encourage the use of wood for energy production.

As well as wood, several countries are also considering agricultural biomass as a source of energy, and the establishment of energy crops is increasing rapidly. Sugar cane and maize (for ethanol production) are examples of energy crops that are expanding fast. The expansion of energy crops and the resulting demand for wood for energy is creating new concerns, however. The demand for agricultural biomass for energy could affect food prices and food security; extensive use of wood could affect forest sustainability and reduce the supply of raw materials for the wood processing industry.

This document was prepared as a background paper for the G-77 countries at the Special Event on Forest and Energy held in Rome on 20 November 2007. It provides general information on the global importance and sources of energy, with special attention to bioenergy in developing countries. In particular, the document covers aspects of recent policies developed by countries to promote bioenergy, the potential competition for land, and opportunities for the forestry sector in developing countries to benefit from future developments in bioenergy.

2. Energy throughout the world

IMPORTANCE OF THE ENERGY SECTOR

The energy sector plays a vital role in the world economy. Throughout recent history, oil prices have affected the economic health of countries, and influenced global economic growth. The adverse economic impact of higher oil prices is felt mainly in developing, oil importing countries.

The International Energy Agency (IEA) points out that a US\$10 increase in the oil price can reduce the growth of gross domestic product (GDP) by an average of 0.8 percent in Asia, reaching 1.6 percent in the region's poor highly indebted countries. The loss of GDP growth in sub-Saharan Africa can be even more, in some countries reaching 3 percent (IEA, 2004).

Table 1 presents the importance of fuels in international trade (both imports and exports) for the world's regions, based on World Trade Organization (WTO) data for 2004. As shown in the table, fuels account for about 11 percent of global trade in merchandise. In some regions, this share is much higher, reaching 73 percent of total exports in the Middle East region, and 52 percent in Africa.

TABLE 1
Share of fuels in trade by region

Share of fuels in total merchandise	% exports	% imports
World	11.1	11.1
North America	7.1	11.7
South and Central America	20.2	15.6
Europe	5.0	8.5
Commonwealth of Independent States (CIS)	43.9	9.8
Africa	51.9	10.2
Middle East	73.0	4.3
Asia	5.1	14.7
Share of fuels in primary products	% exports	% imports
World	48.1	48.1
North America	35.9	58.1
South and Central America	32.7	57.0
Europe	29.9	39.6
CIS	70.2	37.9
Africa	72.9	37.9
Middle East	94.7	24.8
Asia	37.0	53.0

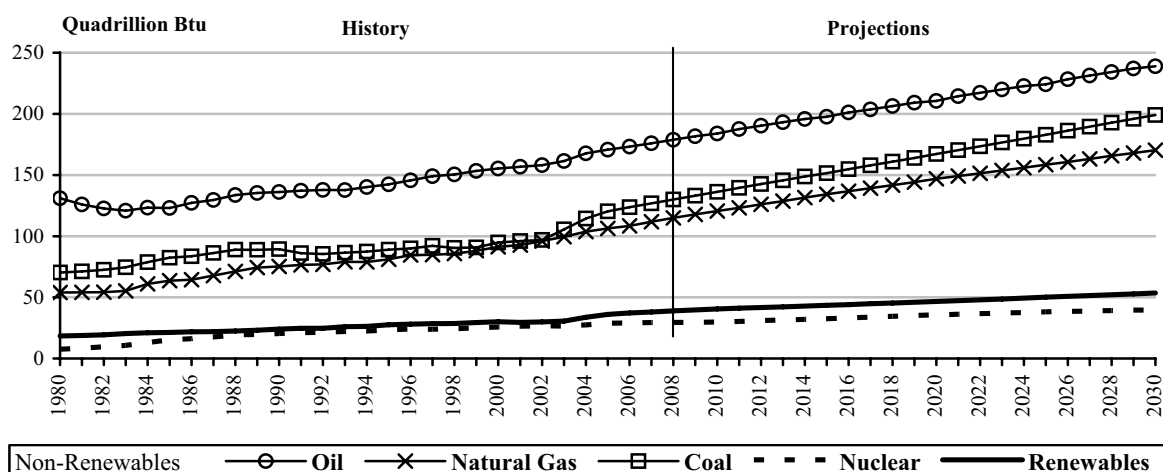
Source: WTO, 2004.

Fuels account for almost half of all the primary products traded worldwide. Fuel exports represent 95 percent of total primary product exports in Middle Eastern countries, and more than 70 percent in CIS and Africa.

GLOBAL DEMAND FOR ENERGY

According to the Energy Information Administration (EIA, 2007), global consumption of marketed energy from all sources will continue to increase over the coming decades. Projected consumption of the main energy sources is presented in Figure 1.

Figure 1. Global marketed energy use by main fuel type, 1980 to 2030

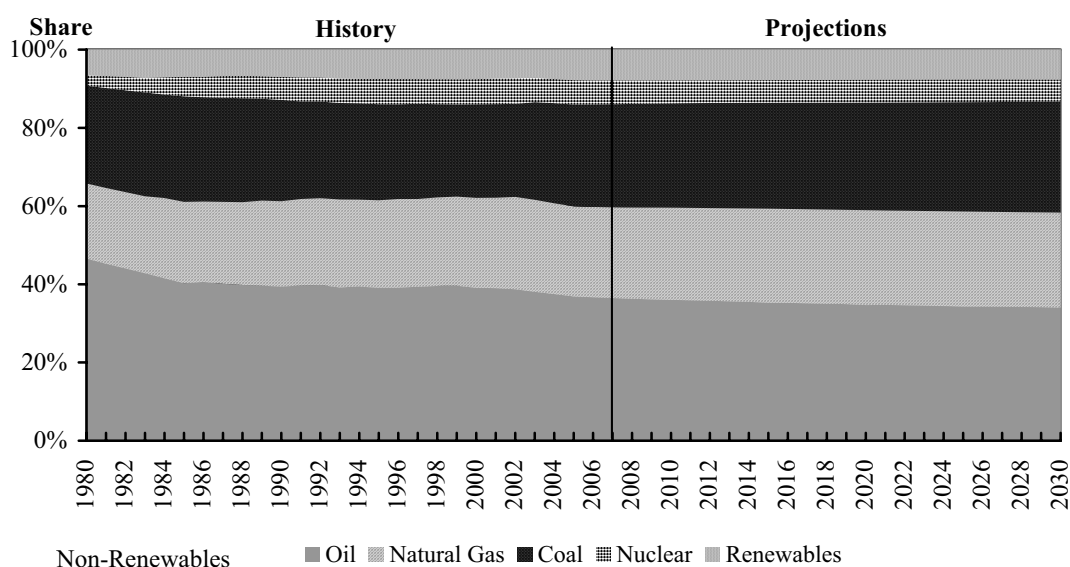


Source: EIA, 2007.

Oil and other petroleum-based products are expected to continue to provide the largest share of world energy in the future, but their contribution to total energy consumption is projected to fall from 38 percent in 2004 to 34 percent in 2030 (Figure 2). This reduction in the oil share is mostly associated with foreseen increases in prices of this energy source over the coming years.

The use of hydroelectricity and other grid-connected renewable energy sources is expected to continue to expand. Based on EIA figures, these sources of energy are projected to grow over the next few decades at a rate of about 1.9 percent per year. A similar growth rate is projected for natural gas.

Figure 2. Global marketed energy shares by main fuel type, 1980 to 2030



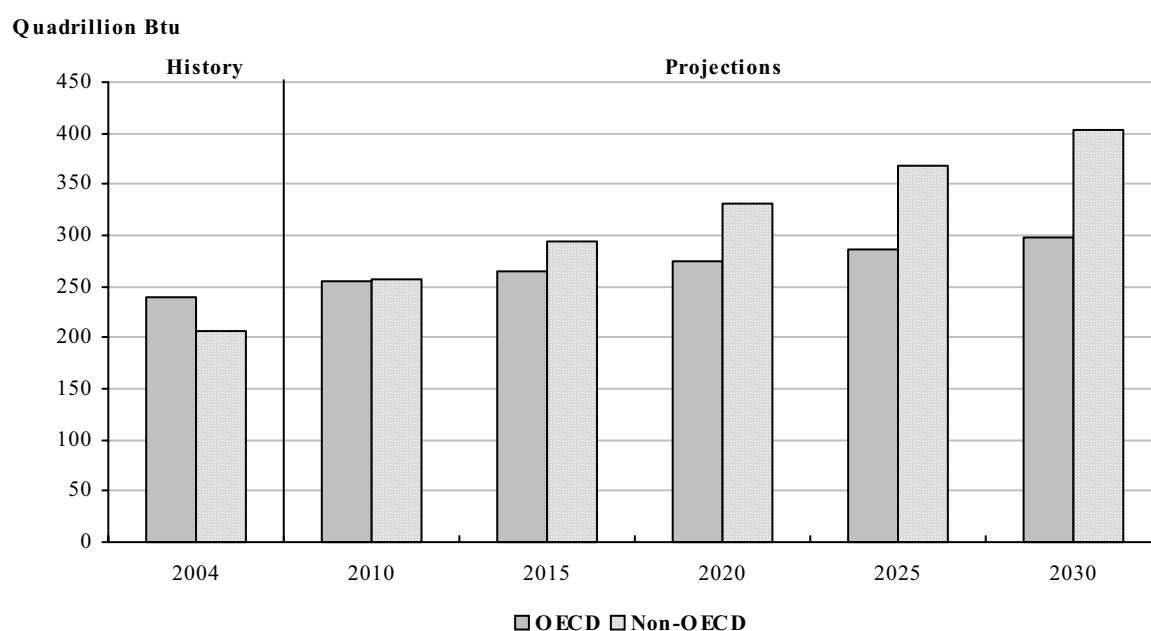
Source: EIA, 2007.

Higher fossil fuel prices, global concerns about climate change and government policies and programmes to support the development of alternative energy will contribute to increasing the competitiveness of renewable energy sources. In spite of national and international efforts, however, the share of renewable energy at the global level will not increase significantly, and is expected to be only 8 percent of total energy consumption by 2030 (EIA, 2007).

The largest increase in energy demand over the coming decades will take place in non-Organisation for Economic Co-operation and Development (OECD) countries, mainly as a result of the strong economic growth and faster population increases that are taking place in these countries.

The projected market for energy in OECD and non-OECD countries, based on EIA studies, is presented in Figure 3. Currently, about 55 percent of global energy consumption occurs in the OECD region, but this share is expected to decline over the next few years.

Figure 3. Marketed energy use in OECD and non-OECD countries, 2004 to 2030



Source: EIA, 2007.

Based on EIA projections, energy consumption in the non-OECD region will grow at an average annual rate of 2.6 percent from 2004 to 2030. In the OECD region, where national economies are mature and population growth is expected to be relatively small, the demand for energy is projected to grow at the much lower rate of 0.8 percent per year. As a result of this significant difference, energy consumption in the non-OECD region is projected to surpass that in the OECD region by 2010; in 2030 the non-OECD countries will account for 57 percent of global energy consumption.

Much of the increase in energy demand in non-OECD members will be a result of fast economic growth in Asian countries, especially China and India. Energy demand in the non-OECD countries of Asia is projected to grow at an average rate of 3.2 percent per year. As a result of this fast growth in demand, non-OECD Asia will more than double its energy consumption over the next 25 years, and is expected to account for more than 65 percent of the total increase in energy demand of all non-OECD countries.

Energy consumption in the non-OECD countries of other regions will grow at a lower pace, but still more rapidly than the global average. Over the next 25 years, projected average annual growth rates for energy consumption are 2.4 percent for Central and South America, 2.3 percent for the Middle East and Africa, and 1.4 percent for non-OECD Europe and Eurasia.

Concerns about global warming and carbon dioxide (CO₂) emissions have gained importance in the geopolitical arena over recent years, and are creating interest in the development and adoption of alternative and renewable sources of energy. Climate change concerns are reflected in the United Nations Framework Convention on Climate Change (UNFCCC) and other global joint efforts and mechanisms created to mitigate climate change, such as the Kyoto Protocol.

There is general scientific consensus that increases in the earth's temperature are largely the result of emissions of CO₂ and other greenhouse gases (GHGs) from human activities, including industrial processes and fossil fuel combustion. More frequent droughts, floods, heat waves and other natural disasters are correlated to climate changes. Expansion of surface water and melting of ice owing to increased temperatures are expected to raise sea levels. Together with other climate change impacts, this will affect the lives of people all over the world, particularly in developing countries.

As a result of these concerns, climate change – together with the increasing prices of fossil fuels and the issue of energy supply security – are now the main driving forces for investments in cleaner energy sources and in more efficient energy utilization, especially in transport and industrial processes.

The growing consumption of fossil fuels for transport has received special attention, and is ultimately associated with the rapid increases in international trade and tourism. According to Deloitte Touche Tohmatsu (2006), fossil fuel use accounts for 45 percent of all CO₂ emissions, one-third of which come from vehicles used to transport goods and people. Since 1990, transport has recorded the fastest increases in GHG emissions in the European Union (EU), Japan and the United States. Urban air pollution is another acute problem in many cities in the developing world, especially in Asia, where it is currently the second most important health impact in urban areas, after water and sanitation.

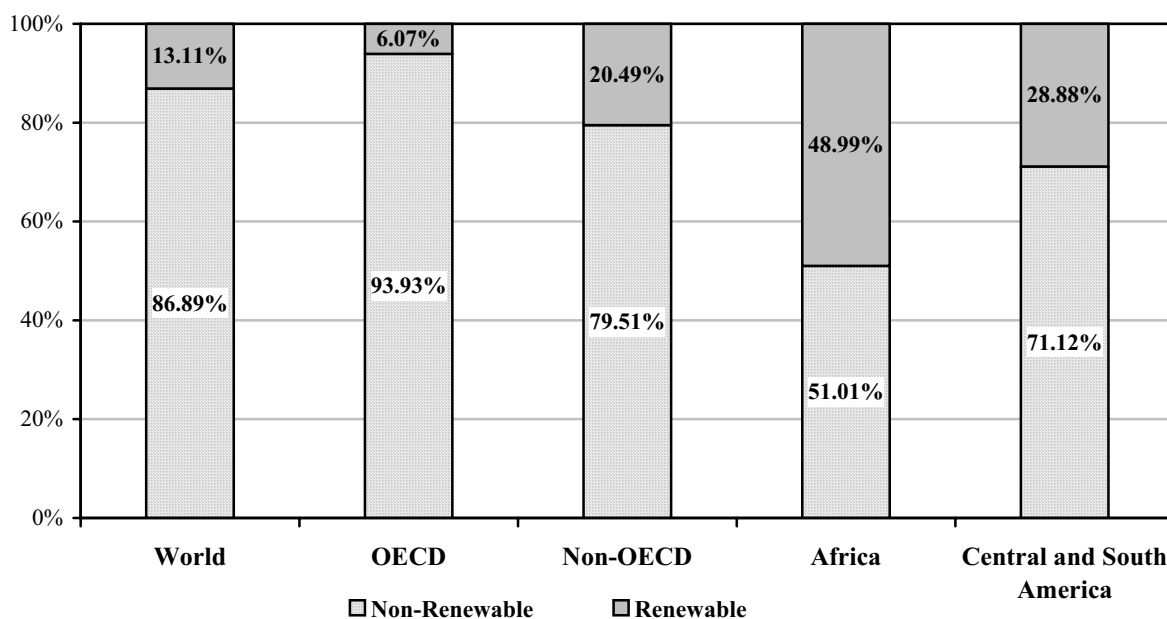
RENEWABLE ENERGY SOURCES AND BIOMASS

Renewable energy consists of energy produced and/or derived from sources that – in principle – can be renovated infinitely such as hydro, solar and wind power, or sustainably produced such as biomass. Biomass is defined as material of biological origin, excluding that embedded in geological formations and transformed into fossil (FAO, 2004).

As previously discussed, the share of renewable energy sources at the global level is very small (currently about 13 percent) and is not expected to change significantly over the coming decades. Figure 4 presents the shares of renewable energy in total energy consumption by region. Only those in Africa and Central and South America are significant.

The high percentage of renewable energy in Central and South America is largely associated with developments in Brazil. About 45 percent of all energy consumed in Brazil is based on renewables, equally divided among three sources: hydroelectricity, wood, and sugar cane ethanol. Currently, Brazil consumes about 90 million tonnes of wood per year for energy generation, which demonstrates the importance of this energy source for the country.

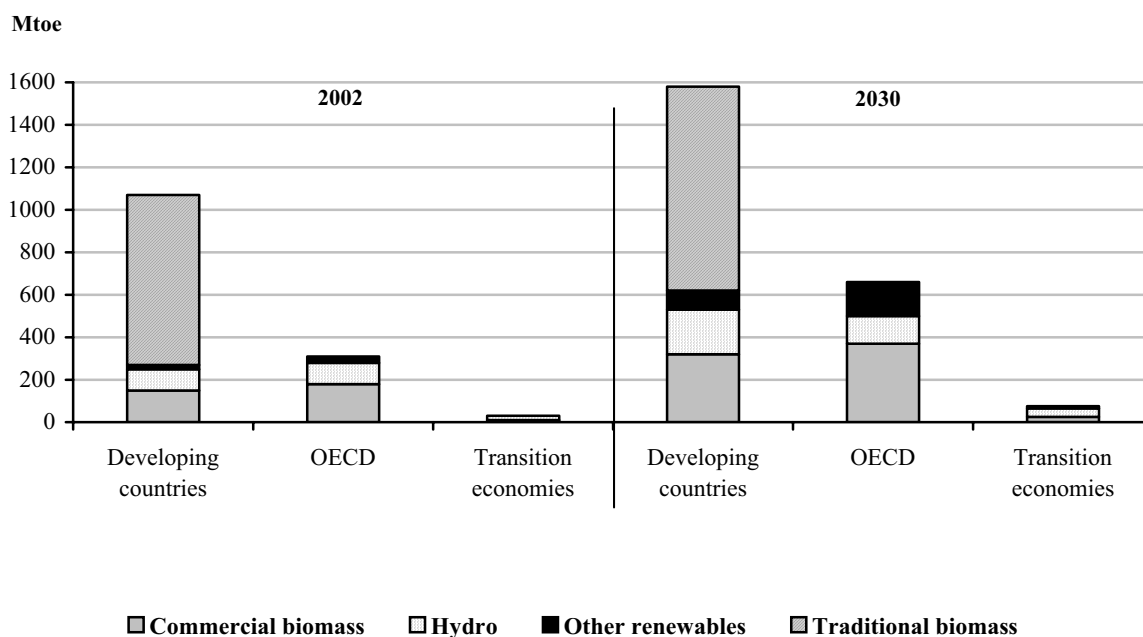
Figure 4. Renewable and non-renewable energy sources



Source: IEA, 2004.

According to IEA (2004), three-quarters of renewable energy is consumed in developing countries, where most renewable energy production is based on the use of traditional biomass and hydropower. OECD countries account for 23 percent of the total renewable energy consumed worldwide, and the transition economies for just 3 percent (Figure 5). Although projections point to developing countries remaining the largest consumers of renewable energy in the future, their share in total global renewable energy consumption is expected to fall to about two-thirds by 2030.

Figure 5. World renewable energy consumption by region



Source: IEA, 2004.

The projected reduction in the relative importance of traditional biomass for energy in developing countries over the next few decades will be the result of several factors, including reduced availability of fuelwood in some regions, increased per capita incomes and increasing urbanization. In the past, these factors have promoted the replacement of traditional biomass by fossil fuels in developed countries.

Although heating and cooking will remain the principal uses of renewable fuels, especially in developing countries, the power sector is expected to lead the global increase in renewable energy consumption over the next 25 years (IEA, 2004). This sector accounted for just a quarter of global renewable energy consumption in 2002, but this share is projected to rise to 38 percent by 2030.

Significant changes are also expected in fuel use for transport, although the impact of these on the global energy consumption matrix will be relatively small. Currently, less than 1 percent of fuels used for transport are renewable; according to projections, this share will rise to 3 percent over the next 25 years.

There is a growing perception that bioenergy offers many potential advantages as an energy supply option, but there are barriers to be overcome before the full potential of bioenergy can be realized. The major potential benefits and possible negative effects resulting from the development of bioenergy systems are presented in Table 2. The list given is not exhaustive, but shows how, in principle, developing countries in particular will be able to benefit from bioenergy systems through the creation of new development opportunities, and increased employment and revenue. There are also potential risks, however. These need to be fully assessed on a case-by-case basis, and include risks to food security, the concentration of land and revenue (especially in large-scale projects) and effects on soil fertility.

TABLE 2
Potential benefits and negative effects of bioenergy systems development

Potential benefits	Potential negative effects
Diversification of agricultural output to feedstock crops for energy	Reduced local food availability owing to replacement of subsistence farmland by energy crop plantations
Development of infrastructure and employment in rural areas	General increase in food prices and potential effects on food security
Diversification of domestic energy supply, especially in rural areas	Demand for land for energy crops may increase deforestation, reduce biodiversity and increase GHG emissions
Facilitated access to energy for rural small and medium-sized enterprises (SMEs)	Increased wood removals above the sustainable production capacity of forests may lead to degradation of forest ecosystems
Climate change mitigation	Displacement of small farmers and concentration of land tenure and incomes
Increased investments in the recuperation of degraded lands	Effects on soil quality and fertility from the intensive cultivation of energy crops
New revenues generated from the improved use of wood and agricultural residues, and from carbon credits	Limitations on the supply of wood for the forest industry, with effects on this economic activity: reduced availability of wood material for construction and other uses, and increased prices
A flexible energy source that can produce heat, power and liquid fuels	

Sources: FAO, 2000; FAO internal communication; UN-Energy, 2007; STCP Data Bank.

The bioenergy sector is experiencing an unprecedented phase of research and development (R&D), from both the public and the private sectors. This will increase understanding and help quantify the potential benefits and risks associated with adopting a bioenergy system within the wider context of biofuels production and utilization. The timing of commercialization is uncertain, but those developing countries that have started to develop bioenergy industries are the most likely to attract investments and benefits from the resulting technology transfer.

3. Bioenergy in developing countries

Biomass is widely used for energy in developing countries, and in many it is the most important renewable energy source, providing an average 75 percent of developing countries' renewable energy demand (IEA, 2004). This chapter discusses traditional uses of biomass for energy, recent developments, and the policies adopted by selected countries to promote bioenergy.

TRADITIONAL USES

Traditional uses of biomass for energy, including fuelwood, charcoal, manure and crop residues, play a major role in many developing countries. This form of energy accounts for most of the energy supply of many dispersed and poor rural populations around the world, and in some countries is also important for industry.

Woodfuels

Much of the wood harvested worldwide is used for energy production. Based on FAOStat (2007) data, global production of roundwood is about 3.3 billion m³ per year; more than half of this total is classified as non-industrial roundwood, mostly used as fuelwood. In addition, part of the wood classified as industrial roundwood is used for energy generation, mainly – but not exclusively – in the forest industry.

Wood has a long history as an energy source and remains a significant one, especially in the domestic sector of rural areas of developing countries. Woodfuels contribute an estimated 7 percent of the world's total energy supply, but they are often viewed as a primitive energy form that is a major cause of deforestation in developing countries. This is because of the belief that most woodfuels originate from forests. A FAO study pointed out that a major share of the woodfuel supply is derived from non-forest areas, however, such as village land, agricultural land, crop plantations, field boundaries, homestead areas and roadsides (FAO, 2000).

In recent years, wood energy has attracted attention as an environmentally friendly alternative, and investments have been made in developing more efficient use of wood residues to expand wood utilization, including for large-scale industrial applications for heat and energy generation. Changes in energy policy in several parts of the world have favoured the development of wood energy-based systems. New biomass energy technologies are improving the economic feasibility of energy generation from wood, particularly in countries that are heavily forested and have well-established wood processing industries.

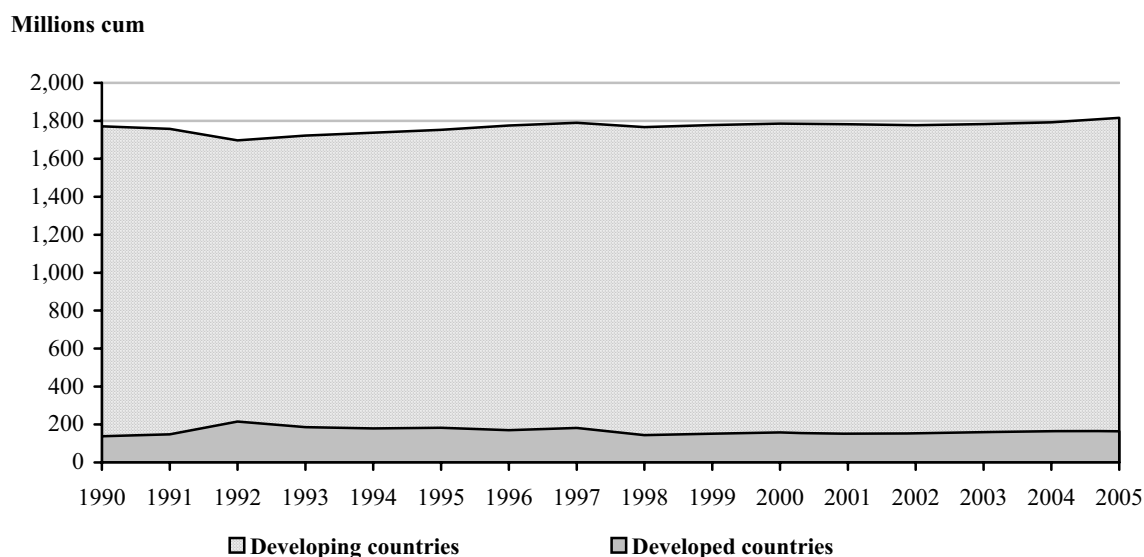
Energy from wood has traditionally been based on fuelwood and charcoal. In recent years, however, as a result of more efficient technology, black liquor has also gained importance, especially in countries where the wood pulp industry is important. Nevertheless, fuelwood and charcoal are still the main sources of energy from wood. Fuelwood is the predominant form of wood energy in rural areas of several developing countries, while charcoal remains a significant energy source in many African, Asian and Latin American urban households.

Fuelwood: As shown in Figure 6, developing countries account for almost 90 percent of the world's fuelwood production. The figure also indicates that over the last 15 years global consumption of fuelwood has remained relatively stable, and is currently about 1.8 billion m³.

Studies in developing countries where fuelwood is used for domestic purposes have found that the inefficient use of fuelwood (and of other bioenergy material) results in significant exposure to indoor pollution. Women, children and the elderly face higher risks, owing to the long hours spent around solid fuel-based fires. According to the World Health Organization (WHO), indoor air pollution is responsible for 2.7 percent of the total disease burden (UNEP, 2007).

Industrial applications are important in many parts of the world, in both developed and developing countries. A large portion of the energy used in the forest industry of several countries is based on wood, and the use of wood in other industrial sectors has also increased in recent years. In Brazil, for example, wood is a competitive source of energy and its utilization for energy generation in the food and beverage industry has increased significantly. In some developing countries, the increasing utilization of wood for industrial energy generation has compensated for the decline in domestic consumption of fuelwood to some extent; this trend is expected to continue in the coming years.

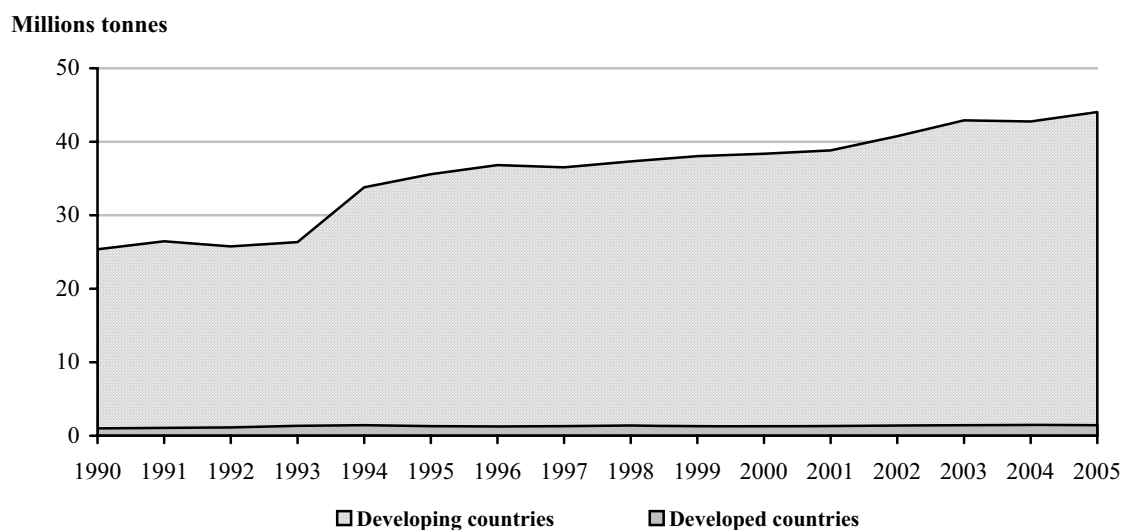
Figure 6. Fuelwood production, 1990 to 2005



Source: FAOStat, 2007.

Charcoal: People have produced and used charcoal as fuel for cooking since the Stone Age, and for producing metal implements since the Bronze Age. In developing countries, charcoal is still widely used in urban and rural areas as a smokeless domestic cooking fuel, with high heat value.

As observed for fuelwood, most of the world's charcoal is produced in developing countries – 95 percent. While fuelwood production has remained relatively stable, charcoal production has increased, rising by an annual 3.7 percent from 1990 to reach 44 million tones in 2005 (Figure 7). The increase in charcoal use for energy seems to be largely associated with expanded industrial applications. Again Brazil is an example of the intensive utilization of this traditional bioenergy source in industry, with most iron ore and steel industry developments now largely based on charcoal.

Figure 7. Charcoal production, 1990 to 2005

Source: FAOStat, 2007.

Agricultural and animal waste

Several animal and agricultural wastes and by-products have traditionally been used for energy generation in many countries. Table 3 presents information on the moisture, ash content and caloric values of selected agricultural by-products commonly used for energy generation.

The use of agricultural waste and by-products is very common in rural areas of developing countries, but industrial-/large-scale use has also gained importance recently. For example, sugar cane bagasse is extensively used in large-scale industrial energy generation. Most modern sugar mills are now self-sufficient in energy and generate surpluses that they sell to the public grid. Animal manure is primarily used in those parts of Asia and Africa where other sources of energy (especially fuelwood) are insufficient to support local demand. This source of energy is normally used for cooking and heating.

TABLE 3
Energy data for selected agricultural by-products

Product	Moisture (% dry basis)	Approximate ash content (%)	Lower heating value (MJ/kg)
Bagasse	40–50	10–12	8.4–10.5
Groundnut shells	3–10	4–14	16.7
Coffee husks	13	8–10	16.7
Cotton husks	5–10	3	16.7
Coconut husks	5–10	6	16.7
Rice hulls	9–11	15–20	13.8–15.1
Olives (pressed)	15–18	3	16.7
Oil-palm fibre	55	10	7.5–8.4
Oil-palm husks	55	5	7.5–8.4
Maize cobs	15	1–2	19.3
Rice straw and husk	15	15–20	13.4
Wheat straw and husk	15	8–9	19.1

Source: FAO, 2000.

RECENT DEVELOPMENTS IN BIOENERGY

In developed countries, biofuels are generally considered old-fashioned because of their bulk and low energy content compared with fossil fuels. This perception changed to some extent during the oil crisis of the 1970s. At that time, increased oil prices stimulated several countries to invest in developing alternative energy sources, including biofuels. With the decline in oil prices that started in the second half of the 1980s, interest in biofuels gradually declined, especially in developed countries. In recent years, discussion of the need to identify alternative and renewable energy sources has resumed. The main reasons for this are associated with a broad range of factors, including:

- growing concern about climate change: when sustainably produced, biofuels are considered carbon-neutral;
- new technologies in biomass conversion, which combined with significant changes in energy markets have improved the competitiveness of this energy source;
- biofuels' unique characteristic as a renewable energy that can be made available in gaseous, liquid and solid states;
- increasing focus on security of the energy supply.

Two trends have emerged from ongoing discussions of bioenergy and developments to increase the role of biomass in the global energy supply (Risø, 2003):

- Developing countries will in general aim to reduce their dependence on traditional bioenergy as part of their development strategies. The relative share of bioenergy in the total energy balance will therefore decline, although the number of people depending on bioenergy will probably remain constant, with corresponding consequences for health and resources.
- Industrialized, and some developing, countries will aim to increase their use of modern bioenergy technologies.

At present, many countries can produce biofuels in large quantities from forest and mill residues, agricultural crops and agro-industrial processing wastes. In many cases, however, the price difference between fossil fuels and biofuels remains a major constraint, and comparisons based on direct cost analysis still usually favour fossil fuels, even considering the recent volatility in international oil prices.

At the current stage of development, other factors need to be taken into account. The international agenda on climate change is one of the most important of these; selecting energy sources based solely on price is too simplistic. The collateral benefits of bioenergy related to energy security (as a country or company strategy) and climate change can offset eventual price differences between biofuels and fossil fuels. In general, policies dealing with energy security are linked to the concept of supply diversification, which is particularly important in times of oil price volatility. Diversification needs to consider the variety of options available, including the different technologies and fuel sources. From this perspective, biofuels offer a broad range of alternatives.

The Clean Development Mechanism (CDM) of the Kyoto Protocol could offer additional incentives for establishing energy plantations and financing the conversion of energy generation systems to sustainable biofuel use. The Kyoto Protocol also facilitates technology transfer to developing countries. In principle, CDM projects should be integrated into national development programmes, and the focus should be on sustainable development. An essential feature of CDM implementation is the balance between contributing to the sustainable development of the host country and the need for the donor country to reduce GHG emissions. CDM projects provide an opportunity to move away from the official development assistance (ODA) framework to a far more private sector-led framework. Because of this, projects funded via CDM are expected to

make an effective contribution to sustainable development and renewable energy investments; modern bioenergy technologies provide significant means of achieving this objective (FAO, 2000).

Government and private investments in biofuels R&D have increased all over the world. This should lead to reduced production costs, higher energy conversion efficiency and greater cost-effectiveness for bioenergy in the future. Research may provide new opportunities for utilizing a wider range of lignocellulosic biomass from timber mills, agro-industries and urban waste, as well as from traditional agricultural and forest residues. Innovations in bioenergy technology is of particular interest to developing countries, because it would allow them to bypass some of the problems of fossil fuel dependency experienced in the most industrialized countries.

In this process, cooperation among countries and particularly the effective use of existing mechanisms for technology transfer to developing countries, such as that provided by the Kyoto Protocol and other international agreements, will play a vital role in giving developing countries the chance to produce competitive biofuels and use them efficiently.

POLICIES AND PROGRAMMES TO PROMOTE BIOENERGY

In recent years, several countries have developed policies and programmes to promote the use of renewable energy sources, and bioenergy has received special attention in many developing countries.

Energy based on forest biomass is one of the most relevant alternatives, but countries also consider several other bioenergy options when defining their policies and priorities to promote the use of renewable energy sources. Examples of initiatives in selected developing countries are presented in the following subsections.

Argentina

The Government of Argentina has recently proposed a general legal framework to promote the development of biofuels. The Biofuels Law (known as SFL) establishes new rules to promote development of the biofuels industry, following the Brazilian model. SFL is based on a combination of fiscal incentives and has set blending quotas for traditional fuels, to create markets and thereby to promote investments in the biofuels industry. The programme makes provision for tax rebates for biodiesel and ethanol producers, including exemption from:

- value-added tax (VAT) on capital goods and infrastructure investments in projects related to biofuels production;
- income tax on activities related to biofuels production;
- hydro-infrastructure tax to reduce the logistics costs of biofuels;
- general fuel taxes.

SFL's target is for 5 percent blends of biodiesel in regular diesel and of ethanol in gasoline by 2010. These provisions aim to encourage investment and provide a consumer base for the biofuels industry. New investment is expected to stimulate the development of infrastructure and technological research. SFL has established an executive body responsible for regulating the biodiesel market and supported by the National Assistant Commission, which suggests policy adjustments related to biofuels.

Both houses of congress approved SFL on 12 May 2006, and the President signed the regulatory framework into law in February 2007. The law's blending targets will create a demand for 600 million litres of biodiesel and 250 million litres of ethanol by 2010.

Brazil

The Brazilian economy was severely affected by the oil crisis of the 1970s. At that time, Brazil was largely dependent on oil imports, and higher international oil prices increased the trade balance deficit, reduced economic growth and made the country extremely dependent on foreign investments and loans. Several new policies and programmes were implemented to reduce the dependence on imported oil, including investments to increase the production of domestic oil and develop other energy sources.

Brazil continued to invest in alternative energy sources even when oil prices declined in the 1990s. This, together with investments in domestic oil production, have completely changed the situation, and the recent oil price increase is not affecting the country as past increases did. As a result of these investments over the decades, Brazil is now world leader in the production of liquid biofuels, and serves as a model for many other countries seeking to establish biofuels as alternative energy sources, develop a new energy economy and reduce fossil fuel emissions.

The first and maybe the most important biofuel programme implemented by the government was the Brazilian National Alcohol Programme to produce ethanol from sugar cane, which was launched in 1975 in response to soaring oil prices and crisis in the international sugar market. Given low international sugar prices, the Brazilian Government sought to utilize domestic sugar supplies to reduce its dependence on foreign oil, improve its balance of payments, reduce disparities in regional supply, expand production and generate employment (IADB, 2006). Efforts focused mainly on the agro-industrial and technological development of sugar cane production. The government embarked on a massive campaign to promote synergies along the supply chain, from sugar cane farmers, to ethanol producers and on to end-users. It also sponsored efforts to produce anhydrous ethanol for blending with gasoline through small initiatives, which expanded and eventually created economies of scale.

Through this programme, from 1975 to 1984, Brazil increased ethanol production from 3.7 billion litres to just over 11.2 billion litres; 2007 production is expected to reach about 18 billion litres. The programme involved not only ethanol producers, but also the transport industry. Its most recent development is the “flex car”, a vehicle equipped with a motor that can run on ethanol, gasoline or mixtures. About 90 percent of all cars now produced and sold in the country are flex cars.

In the early 1980s, a programme supporting the development of biodiesel was created, but its results were on a much smaller scale and the programme was abandoned when oil prices declined. With the recent oil price rises, and from a different perspective, interest in biodiesel has been reactivated. The government’s National Programme for the Production and Use of Biodiesel (PNPB) has created targets for biodiesel blending in diesel of 2 percent by 2008 and 5 percent by 2013. Under the programme, the National Petroleum Agency was renamed the National Petroleum, Natural Gas and Biofuel Agency, and given the tasks of defining biodiesel and its value chain and of authorizing producers (MME, 2004). PNPB’s development targets include:

- diversification of the oilseed plants from which biodiesel can be produced, including expansion of castor bean, jatropha, palms and others;
- production of biodiesel using ethanol as a catalyst, through trans-esterification;
- identification of alternative uses for biodiesel by-products, such as glycerin.

The programme was developed as an umbrella initiative to coordinate the work of the different ministries involved. There are also a number of state-level programmes to promote biofuels, particularly in the growing biodiesel sector. State programmes are in line with the national policy for alternative fuels and are promoted and supported by the federal government. Box 1 gives an example of a state-level initiative – Piauí’s Bioenergy Production Programme.

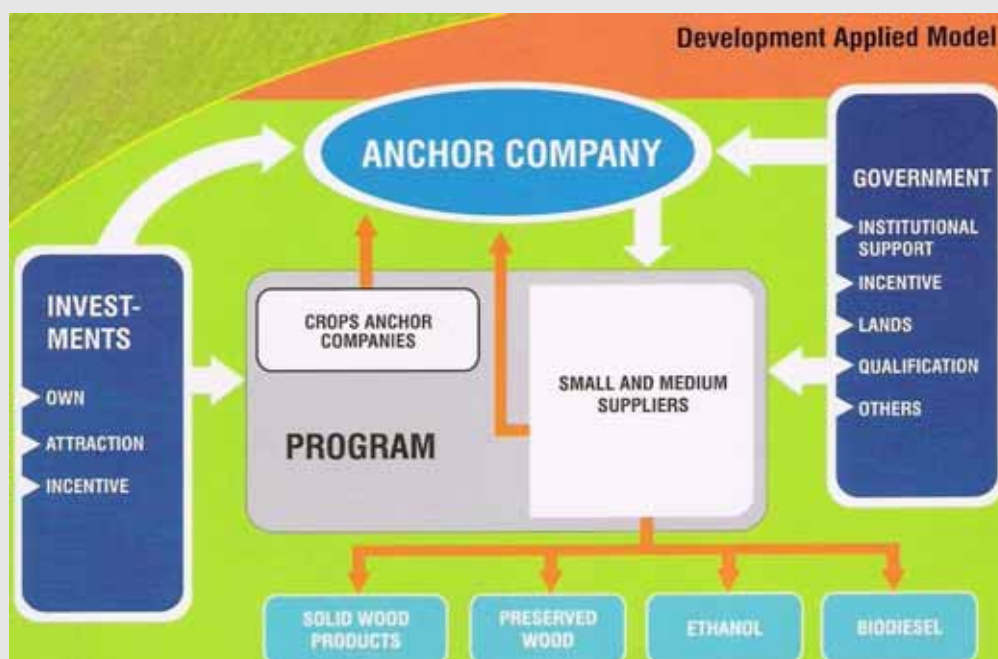
Box 1. Piauí's Bioenergy Production Programme

The federal government's national strategy considers large areas of land in Brazil's southeast as already occupied, and is turning its attention to the central west region as the new frontier for food production. As a result, Tocantins state and southern parts of Piauí and Maranhão states are now emerging regions for biofuels production, and are receiving federal government attention. Besides having extensive areas of available land, these are priority regions for social and economic development; reducing regional development differences is an important national priority.

Taking advantage of the national strategy, Piauí state has made the expansion of bioenergy one of its development strategies. The state government supports agricultural projects to produce oilseeds of different varieties, both native and exotic, including castor bean, soy, sunflower, jatropha and babassu (a native palm).

The Piauí government strategy is based on an integrated development programme that includes forestry and alternative biofuels (see figure below). The programme uses a model based on large industrial enterprises capable of investing in large-scale crops, and of integrating industrial and trading activities. These are "anchor companies" with multiplying effects, which are able to integrate small and medium-sized landowners and enterprises in the production process. The concept considers the government's role to be the creation of an appropriate investment climate, with investments in production coming from the private sector.

The government of Piauí's main objective for this programme is to stimulate the development of an agriculture and forestry-based cluster. It is investing in an improved institutional and legal framework, local infrastructure and support to the private sector in research and human resources development. The target is to consolidate a forest/bioenergy cluster within the next 15 years, to generate employment and increase revenues.



Source: Government of Piauí, 2007.

China

China has a fast-growing economy, which is rapidly increasing the demand for energy. China is becoming dependent on imports of raw materials, including energy that is based largely on fossil fuels. These factors, combined with a large population, are making the country one of the world's main generators of carbon emissions.

China started to invest in bioenergy projects several years ago, following a policy that integrates a range of social, environmental and social approaches. For example, in Hangzhou, the Fushan Collective Farm and Xig Pig Farm projects use anaerobic digestion associated with engines/generators to produce energy for farmworkers' domestic use and the farms' industrial facilities. The liquid effluent is used as fertilizer and fish feed, and the sludge is dried and mixed with potash and phosphate for use as fertilizer. As well as generating income, the projects have reduced the impacts of effluents. In addition, biogas has replaced straw and rice husks as a cooking fuel, which has improved local air quality (FAO, 2000).

Another example of the Chinese integrated approach in bioenergy is a FAO-supported project to develop fuels from sweet sorghum. The grain is used for animal feed, the biogas produced from manure is used to generate process heat and the squeezed bagasse is converted to pyrolytic biodiesel. The experience gained from a pilot is now being used to scale up this approach with a view to producing ethanol.

The Government of China has become increasingly interested in bioenergy developments over recent years. To support the goal of sustainable development, in 2005, the National People's Congress passed the Renewable Energy Law, which came into effect in January 2006 (IADB, 2006). The law aims to promote the development and utilization of renewable energy, including hydroelectricity, wind power, and solar, geothermal, biomass and marine energy. Based on the law, the State Medium- and Long-Term Renewable Energy Development Programme was established with the target of supplying 16 percent of the country's total energy from renewable sources, by 2020. Table 4 presents the programme's specific targets, by energy source. According to the Worldwatch Institute (2006a), this programme has made China the world's largest investor in renewable energy. In 2006, it invested US\$6 billion in renewable energy, accounting for about 16 percent of total global investments in this area (US\$38 billion).

TABLE 4
Targets for renewable energy in China, 2020

Renewable energy type	2020 target
Hydroenergy	300 million KW
Wind energy	30 million KW
Biomass energy	30 million KW
Solar energy	1.8 million KW
Biogas	40.3 billion Cubic Meters
Solar heating	300 million Cubic Meters

Source: IADB, 2006.

Hydro-, solar and wind energy have received most of the Chinese Government's investments in renewable energy, which were bolstered in October 2006 when the Vice Director-General of the Bureau of Energy announced that China would invest US\$187.5 billion in increasing the ratio of renewable energy from 7.5 percent in 2005 to 10 percent by 2010, and 16 percent by 2020.

The renewable energy law also promotes development of the biofuels industry. Article 32 makes the development of biological liquid fuels a priority, including that of ethanol, biodiesel and other biomass-derived liquid fuels. The law's provisions encourage the development of energy crops and the production of biofuels; oil companies will face possible fines if they do not follow fuel blend requirements in the future. The law also singles out renewable energy, including biofuels, as a key area for R&D investments over the coming years. This is expected to improve the efficiency and competitiveness of bioenergy, which is an important priority in a heavily populated country with limited land availability. To reach the 16 percent target for 2020, great efforts and coordination will be required – between 10 and 12 million tonnes of biofuels a year will need to be produced.

India

India imports more than 70 percent of its energy needs and has the second fastest growing motor vehicle industry in the world, after China. These factors have accelerated the government-backed development of a biofuels industry to diversify the national energy mix.

India's huge land mass and long agricultural tradition have the potential to make the country a world leader in both ethanol and biodiesel production. India is heavily populated, however, and has just started its biofuels programme. In addition, it has given priority to producing ethanol from lower-yielding sugar cane molasses and promoting jatropha-based biodiesel, which has not been commercially proven. The viability of the programme therefore remains uncertain.

India is one of the world's largest producers of sugar, which has facilitated the development of sugar cane-based energy. In the 1990s, the local industry made significant advances in developing and implementing sugar cane-based biomass co-generation systems, using bagasse as the fuel source. This system is believed to provide an efficient and sustainable energy alternative that can supply process steam and electricity to local industries, as well as surplus power to the public electricity grid. Co-generation developments in India's sugar mills have been supported by international cooperation. In 1995, a project to mitigate GHG increases, funded by the United States, included a component to finance and support the demonstration of state-of-the-art co-generation technologies. The project concentrated on implementing bagasse/cane trash handling, storage and utilization for energy generation. It also made direct grant assistance available to several sugar mills (FAO, 2000).

In 2002, rising oil import bills prompted the Indian Government's Planning Commission to establish the Committee on Development of Biofuel, in a bid to diversify the national energy mix. In April 2003, the commission submitted a report on the country's potential in biofuels and recommended establishing a National Mission on Biodiesel. To improve coordination of the different ethanol and biodiesel policies that have since been implemented, the Ministry of New and Renewable Energy is drafting a National Policy on Biofuels. One of its recommendations is the creation of a national biofuel development board, to be headed by the Prime Minister (Government of India, 2003).

Indonesia

Indonesia's national energy policy is overseen by the Agency for Coordination of National Energy. In 2005, the agency launched the Green Energy Initiative 2020, which calls for the maximum and most efficient utilization of renewable energy and the development of clean, high-performance fuels. The initiative aims to increase the share of biofuels and biomass in the national energy mix from today's 0.2 percent to 20 percent by 2025. To support such lofty biofuels production goals, the Ministry of Energy has estimated that Indonesia will need to raise US\$22 billion over the next five years. This would help finance the government's plan to turn at least 5 million ha of former forest land into plantation land for oil-palm, jatropha, sugar cane and cassava, as well as funding the US\$110 million promised to farmers to help them plant biofuel crops.

The plan is still in its early stages, however, and there are financial limitations. To organize financing, the government is investing US\$22 million in setting up a venture capital company to manage the US\$2.5 billion it intends to seek from multilateral institutions such as the Asian Development Bank and private investors. The company would offer up to 70 percent financing for biofuels projects in Indonesia (IADB, 2006).

Indonesia's plans have been heavily criticized, however. Some non-governmental organizations (NGOs) report that about 12 million ha of land has been deforested for oil-palm plantations, even though Indonesia's palm-oil yields continue to be well below the global average. It has also been reported that the growing demand for palm-oil for exports, partly driven by bioenergy demand, has resulted in increased prices for cooking oil in the domestic market, which have affected poor people in particular (Ernsting, 2007).

Mexico

Although Mexico is a net exporter of oil, biofuels development could enhance domestic energy security through diversification and displacing part of the 30 percent of domestic consumption currently imported by Petroleos Mexicanos. In addition, biofuel production could also alleviate rural poverty in some regions, making a domestic biofuels industry a potentially attractive socio-economic development strategy. The biofuels industry could help to diversify the country's troubled sugar cane sector and reduce GHG emissions.

This strategy is reflected in Mexico's Renewable Energy Programme, created in the 1990s with United States support. The programme aims to promote the use of renewable energy systems, enhance economic and social development, create new business opportunities, and offset GHG emissions. Throughout the 1990s, the programme focused on productive uses of renewable energy systems in rural, off-grid areas, mainly through solar and small-scale wind generation. The energy was to be used in pumping water for irrigation and/or livestock, and in communications and lighting for ecotourism facilities. The programme resulted in the installation of several hundred renewable energy pilot projects, mainly for water pumping and electrification.

The impact of these efforts in the 1990s were not significant, however. By 2003 renewable energy sources accounted for only 5.1 percent of Mexico's total primary energy supply, a relatively small share for a developing country. The government has expressed a desire to increase this share to 8 percent by 2012, and passed a law establishing government funds to support the implementation of renewable energy projects. Among other aspects, this law stipulates that the producers of electricity based on biofuels may sell excess production to the national electricity system.

Recent studies by the Mexican Government estimate that bioenergy could supply 54 to 85 percent of domestic energy needs, but this seems over-optimistic given the present energy matrix. The studies estimate that 27 to 54 percent of energy could be derived from woodfuels, 26 percent from agrofuels, and 0.6 percent from agrofuel by-products (Bremauntz, 2006).

Investments in the domestic biofuels industry would create significant socio-economic benefits for Mexico by generating employment, preserving the environment and providing a market for excess sugar supply. It seems that developments are still in their early stages, however, and a clearer policy, supported by structured development programmes, needs to be put in place.

South Africa

Historically, the incentives for investing in energy-efficient technologies and renewable energy have been weak in South Africa, partly owing to the country's inexpensive and abundant coal resources. South Africa also faces increasing competition for land and water resources, and food security is a priority. This has limited the expansion of industrial forest plantations, which could be a feasible option for bioenergy production in South Africa.

In November 2003, the South African Minerals and Energy Department drafted its first White Paper on Renewable Energy, which sparked initiatives in a number of renewable energy technologies – including biomass, wind, solar and small-scale hydropower projects – by defining market rules, sources of financing and required technologies for new entrants in the sector (IADB, 2006). The Gas Act (Act 48 of 2001) and the amended Petroleum Products Act also provide a basis for the integration of renewable energy-derived liquid fuels, such as biodiesel and ethanol, into the petroleum industry's regulatory framework.

Crops under consideration for biodiesel production include sunflower, rapeseed, soybean and jatropha. It is estimated that the agriculture sector has the potential to produce more than 1.4 billion litres of biodiesel per year from these oilseed crops. This could be achieved in two ways: 650 000 ha of commercial maize production could be converted to oilseed production; or the government could implement a programme to revitalize agricultural production in disadvantaged rural areas. The latter would make 2.3 million ha of land available for oilseed crop production. Either approach would contribute more than 20 percent of South Africa's diesel consumption of 6.8 billion litres a year.

4. Competition for land and food security

The production of biomass for large-scale energy generation requires extensive land areas and is labour-intensive. It also demands significant investments; the use of advanced technology is important for competitiveness. Land is a key factor in the production of bioenergy resources, which can mean that less land is available for producing food. As a result, food security is a concern for some countries, particularly those with limited land resources and high populations.

Food and energy have important links. Agriculture is itself an energy process, as through photosynthesis it transforms solar energy into food energy for humans and animals (FAO, 2000). It also produces residues that can be used for energy generation. Agriculture, particularly modern agriculture, requires energy inputs at all stages of production, such as for farm machinery, water management, irrigation and the transport of products to markets. Large amounts of energy are also consumed in activities associated with agriculture, such as the production of fertilizers and food industrialization. The energy consumption of agriculture in industrialized countries is quite high, and tends to increase in developing countries as they move towards more advanced cultivation practices.

It is therefore imperative to ensure that sufficient cropland is available to produce food for the world's expanding population, while it is also important to regard energy as a key issue; biomass energy can help enhance development, especially in developing countries. Studies indicate significant reserves of potential cropland, but these resources are not distributed where they will most be needed, according to present predictions for population growth and land-use competition (Risø, 2003). Land availability varies among regions and within regions and countries. For example, some Asian countries with high populations appear to have no, or only very limited, spare land for bioenergy production.

Even in heavily populated Asian countries, however, strategies such as agroforestry, efficient energy conversion technologies and the use of agricultural wastes could create significant amounts of bioenergy. Latin America, much of Africa and some forest-rich countries in Asia have large areas that could be used for bioenergy, but in some cases competition with forest reserves, nature protection and biodiversity conservation can impose limitations on this. In other countries there are large areas of deforested and degraded land that could benefit from the establishment of biomass plantations. Several studies indicate that there are still large potential cropland resources available in several developing countries (Risø, 2003). This indicates that energy crops need not threaten food security, at least over the next few decades, and that land-use competition between agriculture and energy crops can be minimized through the use of degraded and surplus agricultural land targeted for energy crops.

If prices of biofuel crops rise significantly, farmers will tend to convert food croplands to energy crops. At first, this will reduce food supply, and food prices will increase. It has to be noted, however, that farmers shift cultivation quite frequently, and their crop decisions are based mainly on market prices and profitability. This means that higher food prices would make farmers return to food crops, so the market would act to restore the supply–demand equation. In other words, the problem is associated with price fluctuations, and not food security *per se*. Nevertheless, any increase in food prices, even if only transitory, would affect poor people, especially in developing countries.

There are indications that this is already happening to some extent. The recent increases in dairy product prices has been correlated with growing demand in China and reduced milk production in the United States, which in turn seems to be associated with higher maize prices resulting from the additional demand created by ethanol producers. Another example comes from South Africa. Traditionally, this country has produced surplus maize and sugar, so these crops

could become important feedstocks for ethanol production, without affecting food security. As a result, agrofuels became one of the priorities of the government's Accelerated Growth Initiative, with the Industrial Development Corporation and the Central Energy Fund announcing plans to invest US\$437 million in five agrofuel projects. Over the past year, the "ethanol effect" – coupled with a drought in southern Africa – has caused maize prices to increase significantly. Maize is the country's staple food, so it is the poor who suffer most (GRAIN, 2007).

In many developing countries, food and fuel production can be integrated into complementary land-use systems. For example, a small- to medium-scale plant for energy generation (100 kW to 1 MW), using the agricultural residues produced in relatively small agricultural communities, can make sufficient energy available to cover domestic water, irrigation, lighting and cooking needs.

Irrigation can greatly increase crop yields, and water is another potentially scarce resource. At the small to medium scale, although the use of indigenous biofuels does not necessarily consume land resources, it may consume water. To mitigate the effects of this, any excess biomass produced could be converted to higher-value energy products, such as charcoal, electricity or synthetic biofuels, which can be sold on the open market. Fuelwood and charcoal are already significant income sources in rural areas of many developing countries.

Large-scale energy production operations concentrated in a region can create land-use conflicts, as large energy plantations are required to supply central conversion facilities. Biomass is generally a low energy-density fuel, and the resulting high transport costs require that conversion facilities secure supplies from land located as nearby as possible; this might displace traditional farmers and provoke landownership concentration. Under these conditions, government measures to protect the small farmers near the conversion facilities and to regulate other land-use issues may be necessary. These concerns must also be measured against the benefits arising from the presence of conversion facilities: increased rural employment (for all skill levels), a secure market for agricultural products, the provision of cheap indigenous supplies of energy, and reductions of greenhouse effects.

When coupled with agroforestry and integrated farming, bioenergy programmes have the potential to improve food production by making available both energy crops and incomes. The agricultural production of biomass can be increased by substituting agricultural crops that are in surplus, intermixing energy crops with food or forage crops according to an agroforestry approach, and incorporating land conservation systems such as windbreaks and shelter-belts. There is also potential to increase the use of crop residues, provided this is consistent with maintaining organic matter levels and controlling erosion.

Countries developing bioenergy programmes can consider an extensive range of biomass sources, including agricultural and forest residues, and production of energy crops such as sugar cane, switchgrass, oilseeds, wood and elephant grass. These biomasses can be converted by fermentation, gasification and combustion into different forms of energy, including heat, electricity and liquid fuels. This demonstrates the great opportunities that developing countries have for exploring biomass, not only from energy crops, but also from agricultural and forest residues. When proper provisions are made, biofuel production need not have implications on food security.

5. Forests and bioenergy

OPPORTUNITIES FOR DEVELOPING COUNTRIES

Increased fossil fuel prices, global concerns about climate change and, in particular, mechanisms such as those created by the Kyoto Protocol provide opportunities for bioenergy production in developing countries. Several such countries have great potential for increasing the production of bioenergy from wood and other biomass, generating employment and revenue while contributing to global efforts to reduce GHG emissions.

Wood is a traditional fuel and one of the major options for satisfying future energy demand from renewable sources. In many developing countries, wood energy produced with efficient technology is already competitive with fossil energy. As well as being economically attractive, wood energy can be a strategic option to increase energy security, which is particularly important in countries that have large forest areas, but that depend on energy imports.

In dealing with forest-based bioenergy, developing countries should assess their own abilities to produce competitive energy, following a phased approach with two strategic steps. To reduce costs and risks, this approach recommends that developing countries should first explore the opportunities for producing energy based on traditional technology and existing technology, before moving on to the second step, when investments are made in dedicated energy-based projects and the development of new technologies. Some aspects of this approach are presented in the following subsections.

Opportunities based on traditional technology



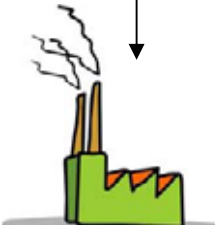
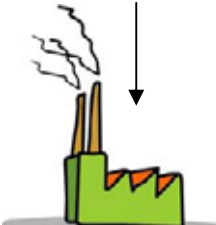
In countries with large forest areas and an active forest industry, several opportunities can be explored for making significant gains from energy generation using proven technology. This first step should be a priority, as it minimizes investments and risks.

Most countries have no clear perception of the amount of biomass that can be collected from ongoing forest operations, and have never assessed the full potential of wood residues for energy generation. Figure 8 provides some general information on the wood residues available from industrial operations, based on typical industrial operations in Brazil using two different wood sources: fast-growing pine plantations, and natural forest in the Amazon region.

Figure 8 indicates that only a small portion of the wood produced from forests is converted into market products. In natural forests, between 80 and 90 percent of total volume is residues that can be used for energy generation. Most of this material is made up of tree crowns and other rejected pieces that are left in the forest after harvesting operations. Although the data in this example were collected from the Amazon region, they could also apply to forest/industrial operations in other tropical regions. The percentage of wood residues generated in forest plantations is smaller, but still significant.

It is worth noting that although in some cases the timber industry uses part of the residues to generate the energy it requires, in developing countries there are usually excess wood residues at mill sites, which create environmental problems by affecting water and air quality. These excess wood residues at mill sites provide a good opportunity to produce energy, including excess energy to sell on the market. This would reduce the dependence on oil energy generation, which is common in the remote areas of developing countries where the timber industry operates. When using residues to generate power, proven combustion technology should be used, combined with simple steam machines for small-scale power production, or steam turbines for larger power plants (ITTO, 2005).

Figure 8. Forest industry operations and wood residues

Operation	Natural forest	Plantations
Harvesting	 <p>100 ↓ Logs (30-40) → Crown and rejects (60-70)</p>	 <p>100 ↓ diameter Logs (80-90) → Crown/small and other rejects (10-20)</p>
Primary and secondary processing	 <p>Final product (10-20) → Bark Cutting Sawdust Shaving Others (10-20)</p>	 <p>Final product (30-40) → Bark Cutting Sawdust Shaving Others (40-50)</p>
Wood residues	80-90%	60-70%

Sources: ITTO, 2005; STCP Data Bank, adapted.

Table 5 presents estimates of wood residue availability, calculated from International Tropical Timber Organization (ITTO) data for industrial log consumption in selected countries (ITTO, 2006), and the potential production of electricity. The estimates are based on the utilization of a steam condensation turbine for electricity production and an average low calorific value for tropical timbers.

As Table 5 shows, a considerable amount of energy is potentially available from wood residues. In some countries, such as Cameroon, the wood residues generated at mills alone would be sufficient to supply the country's total electricity demand (3 320 GWh). Were all the residues resulting from forest operations in Cameroon to be used for electricity generation, the country would be able to produce five times its current demand.

Wood residues from mills could also produce a significant portion of the electricity consumed in Gabon (60 percent), Nigeria (12 percent), Malaysia (8 percent) and Brazil (7 percent). In other countries, such as India, Thailand, Colombia and Peru, the potential contributions of wood residues to total electricity consumption are relatively small, varying from 1 to 2 percent.

It is worth remembering that wood residues from mills represent only a small portion of the total residues available. The volume of wood residues left from harvesting operations in tropical forests is three to six times that generated at mills. It is important to have efficient harvesting and transport technology for collecting this material and delivering it to power plants, in order to reduce costs, mitigate possible environmental impacts and make possible the production of competitive power from this fuel source.

TABLE 5
Electricity generation potential of wood residues in selected countries

Country	Log consumption (1 000 m ³)	Wood residues (1000 m ³)		Electricity generation potential (GWh) ^b	
		Industry	Total ^a	Industry	Total
Africa					
Cameroon	16 960	7 100	38 600	3 550	19 300
Nigeria	7 100	3 000	16 200	1 500	8 100
Gabon	3 320	1 400	7 300	700	3 650
Ghana	1 175	500	2 700	250	1 350
Asia					
Malaysia	29 170	12 300	66 500	6 150	33 250
Indonesia	24 220	10 200	55 200	5 100	27 600
India	16 000	6 700	36 400	3 380	18 200
Thailand	8 200	3 400	18 200	1 700	9 100
Latin America					
Brazil	120 000	50 400	272 800	25 200	136 000
Colombia	2 840	1 200	6 400	600	3 000
Peru	2 310	970	5 300	480	2 650
Ecuador	1 900	800	4 300	400	215

^a Includes residues from harvesting operations.

^b Based on use of a steam condensation turbine.

Sources: ITTO, 2006; STCP Data Bank.

New wood sources and technology developments

Among the new opportunities for developing countries regarding energy generation from wood are energy crops, management of natural forest to maximize the sustainable production of biofuels, and new technologies for wood processing for energy generation. These require higher investments and therefore have higher risks. Aspects of these options that are relevant to developing countries are discussed in the following paragraphs.

Energy crop forest plantations: Forest plantations dedicated to the production of wood for energy have existed in many countries for some time (NAS, 1980), so in theory energy crops are not an innovation. On the other hand, most of the energy plantations around the world are on a small scale, use poorly developed technology, and focus generally on the supply of fuelwood for local consumption.

Brazil is one of the few countries where the large-scale production of energy from wood has been explored over recent decades. Significant investments have been made in plantation forests, mostly of fast-growing eucalyptus, dedicated to the production of wood for industrial charcoal to feed the steel industry. Brazil has also developed forest plantations to produce biomass for combustion and generation of heat and electricity for the food, beverage and other industries.

High productivity of plantations, efficient harvesting and good logistics are fundamental to producing biomass at costs that allow energy generation at competitive prices for the market. Countries exploring this opportunity need first to put in place the conditions for efficient production of biofuels from plantations. This requires the development of appropriate genetic material for local conditions, and the use of advanced technology for silviculture, plantation management, harvesting, transportation and energy conversion.

Although this may seem to be relatively simple, some developing countries will require several years of investment in R&D before they can adopt the technology required to make energy crop plantations an attractive business. The risks associated with such ventures can be mitigated by using known and well-established species/genetic material (such as eucalyptus); new species should generally be avoided. Countries and investors also need to be aware that they are dealing with a long-term investment with risks. One important risk that is outside the control of countries and investors is associated to the fluctuations in energy prices over time.

Investors also need to consider that forest planting and management for biomass is not compatible with the forest industries currently operating in most developing countries, especially the less developed ones. Changes in energy prices may render energy crop plantations unviable, and consequently of no market value. This is less of a risk for countries with more developed forest industries, which can adapt the biomass to other uses. The wood pulp and reconstituted wood panels industries are examples of operations that use these raw materials, so the existence of such industries reduces the risk for investments in energy crop plantations.

Management of natural forests for energy: There are several innovative opportunities in the management of natural forests. As discussed previously, the harvesting of natural tropical forests leaves behind large quantities of wood. This potential source of biomass for energy has yet to be explored in most developing countries.

Box 2. Sustainable forest management of tropical forests and energy generation

An ITTO project on energy generation from forest biomass demonstrates that combining the traditional forest products industry with non-traditional timber production for energy generation can improve the timber industry's profitability and promote sustainable forest management in the tropics.

The study was carried out in four locations in the Amazon region, and assessed wood residues generated by harvesting operations and the wood industry, and biomass from LKS/LUS. It found that residues generated at the mill represent only a small portion of all the residues produced throughout timber operations, starting in the forest. The study calculated that only 5 to 10 percent of the total wood biomass ends up as wood products traded in the market. The rest is left in the forest as harvesting residues or non-harvested LKS/LUS, or it is generated as residue at the mills. The remaining 90 percent (or more) of total wood volume provides enormous potential for energy generation.

The study analysed the generation of electricity from small- and medium-scale power plants (of 2.0 MWh to 10 MWh) using traditional technology (wood combustion and steam turbine). Financial and economic analysis demonstrated that electricity generation from forest and industrial wood residues is a feasible option compared with the prices for energy produced from fossil fuels.

The study found that investments per installed megawatt capacity are relatively high, especially for smaller power plants, and returns are highly sensitive to energy market prices and biomass costs. This means that biomass generation cannot compete in countries where fossil fuel use in power plants is subsidized. The results also demonstrate that the use of forest residues is feasible only when the material can be harvested efficiently and transportation distances are relatively small.

The study concluded that the use of LKS/LUS for energy generation provides an important opportunity for improving the cost-efficiency of total forest operations, while helping to make the harvesting and use of wood residues for energy generation a feasible option.

Source: ITTO, 2005.

The wood of species that for various reasons are not used by the timber industry – such as less-known or less-used species (LKS/LUS) – represents another opportunity. A recent study (ITTO, 2005) analysed the option of combining the harvesting of traditional species for the timber industry with that of LSK/LUS wood for energy in management plans. Energy generation following this approach could increase revenue and improve sustainable forest management. Box 2 provides some of the main findings of the ITTO study.

Another innovative opportunity is the management of secondary natural forests to produce biomass for energy generation. In tropical regions, secondary forests are fairly extensive. This type of forest has large volumes of biomass that cannot be used by traditional wood-processing industries, representing a potential source for energy generation. Application of the ITTO guidelines for managing secondary forests (ITTO, 2002) can promote the sustainable development of this opportunity.

New technology for wood-based energy generation: Countries that have already fully exploited their traditional sources of forest biomass for energy can consider developing innovative and more advanced technologies for energy generation from wood. There are several alternatives in this context, with advanced research prioritizing the production of liquid biofuels to support the growing demand for energy in the transport sector. This opens new vistas for the use of wood for energy, which is currently concentrated in combustion technology to produce heat and electricity.

The development of technologies to produce competitive liquid biofuels from cellulosic biomass is critical to achieving wood's full potential as an energy source. Liquid fuels can be produced from wood through the use of several known technologies, including gasification (a thermal pathway) and hydrolysis (a biochemical pathway). The challenge is to find ways of lowering the costs of liquid fuel production from cellulosic biomass by improving existing conversion technologies (Worldwatch, 2006b). So far, the liquid fuels produced from wood are more expensive than those from other bioenergy sources, especially ethanol produced from sugar cane.

The development of technologies that make it possible to produce competitive liquid fuels from wood will require time and significant investments in research. To be competitive, large-scale facilities are also required, for which high investments are needed (especially for gasification). The risks associated with this option are also relatively high, so developing countries should explore other options fully before embarking on this venture.

THREATS AND IMPLICATIONS

Bioenergy provides many new opportunities, and can contribute to reducing poverty in developing countries. It can also have important strategic implications by contributing to increased energy security, particularly for oil importing countries; restoring unproductive and degraded lands; and promoting development in other sectors of a country's economy through, for example, improved agricultural productivity. Bioenergy has the potential to help reduce GHG emissions, which are a global concern.

However, it has to be recognized that there are problems associated with biofuel production, especially regarding large-scale operations. It is important that problems are fully understood so that risks can be minimized and benefits maximized.

Competition for land and the implications for food security are an important aspect, and it is fundamental that sufficient cropland be available to produce food for the world's expanding population. Although this issue is discussed in chapter 4, it is worth stressing here that the large-scale production of biofuels requires extensive land areas, and there are concerns that biofuel crops could affect food security. To deal satisfactorily with land-use issues and their implications on

forests, biofuel production could be expanded under one or a combination of the following scenarios:

- Land currently dedicated to food crops is converted to bioenergy crops (including wood energy crops) and/or degraded areas are used. Such an approach is not expected to have any impact on forests. There could be an impact on food security, however, especially from large-scale operations, unless productivity is increased and/or synergies between food and energy production are tapped.
- Bioenergy crops are introduced into forested areas, which implies deforestation. This would have impacts on biodiversity and other forest goods and services, and would increase GHG emissions, with negative implications for climate change. In this scenario, depending on the degree of expansion of the bioenergy crop(s) and the reduction of the forested area, wood-based industries could face reductions in raw material supplies, and the market demand for construction materials and other wood products may not be satisfied.
- The wood produced from existing industrial forests is diverted to the energy sector. This would have an impact on the management practices for natural forests and plantations, and would increase competition for resource among wood users. The volumes available to the forest industry would decline and the costs of raw material increase, with possible effects on wood products markets.
- The efficiency of wood use is increased by optimizing industrial processes and using harvesting residues, LKS/LUS material, mill residues, recovered/urban wood and other by-products to produce bioenergy. Under this scenario, significant amounts of energy could be generated, and the impacts would be minimized.

The following paragraphs describe some of the threats associated with the biofuels production, focusing on the socio-economic and environmental implications. The main environmental impacts are related to soil and water resources, biodiversity and climate change. Economic risks associated with large bioenergy projects in developing countries are also mentioned.

Bioenergy projects have *social and economic implications*. Many studies report that developments in bioenergy are an option for reducing poverty in developing countries. On the other hand, social conflicts can also be provoked by the presence of large energy plantations supplying a central conversion facility. Biofuels should be produced close to the conversion facility, but this tends to concentrate landownership and may displace traditional farmers. As a result, in some parts of the world, there is resistance to agrofuel projects. In Uganda, for example, there were public reactions after the government granted a permit to a company to exploit the Mabira forests for planting sugar cane for agrofuels. Similar reactions to agrofuel projects have also been reported in Ghana, South Africa and other countries (GRAIN, 2007).

In most developing countries, where traditional bioenergy is important, energy provision is normally a labour-intensive activity, and thus a significant source of formal and informal employment. The modernization of bioenergy production, increasing the scale and productivity, may reduce the demand for labour, which could have a negative socio-economic effect. The labour demand will still be higher than that for energy production from fossil fuels, however, and increased productivity can result in higher revenues, so the overall balance is expected to be positive.

It is important to consider the social implications of bioenergy developments, especially those in developing countries, from a broader perspective. These developments will make energy available to rural populations that have limited access to other energy sources, and this can increase agricultural productivity and promote the development of local businesses. Indirect benefits should also be explored. Bioenergy developments can reduce the indoor air pollution that increases infant mortality and reduces life expectancy in many developing countries. The situation

in poor households that currently depend on traditional biomass could be dramatically improved if bioenergy development considers such aspects as promoting the more efficient and sustainable use of traditional biomasses and enabling people to switch to modern cooking fuels and technologies (UN-Energy, 2007).

Biomass sources are more spatially dispersed than fossil fuels, and such dispersion tends to increase harvesting and transportation costs. It is important to reduce these costs to increase profitability by concentrating energy crops, especially for large-scale production. The concentration of biomass production and the search for productivity gains for biofuel crops increase the potential risks associated with *soil depletion and erosion*, however.

Intensive cultivation also increases and concentrates *water consumption*, a scarce resource in some countries. Some agrofuel crops consume large quantities of water. In March 2006, the International Water Management Institute issued a report warning that the rush for biofuels could worsen the water crisis in some countries. For example, in China and India, water resources are scarce and a large share of agrofuel crop production depends on irrigation (GRAIN, 2007). This can reduce the water resources for food crops and have impacts on food security.

It should be remembered that there are extensive degraded lands available in many developing countries, and the planting of trees or other energy crops in these areas might be a way to reduce erosion, restore ecosystems and even regulate water flows. To realize these benefits, the expansion of biofuel production will need to be accompanied by a new generation of clear and strict land-use regulations, particularly in countries with tropical forests that are at risk of destruction (Worldwatch, 2006b).

The use of agricultural and forest residues could significantly reduce the land requirements for biofuel production, thereby reducing the impact of fuel crop plantations. It is important to recognize that such residues are necessary for maintaining soil and ecosystem health, however, so certain amounts of them should remain on the ground. Logging residues are an important source of energy, but are also a source of forest nutrients, which help protect soils from rain, sun and wind, reducing the risk of erosion (UN-Energy, 2007).

Biomass is a potentially carbon-neutral source of energy that is renewable and could therefore provide an means of mitigating climate change through the replacement of fossil fuels. On the other hand, there are also concerns that the growing demand for biofuels will increase deforestation and affect forest sustainability. The result would be negative *impacts on biodiversity and natural resource management*, as well as potential increases in *GHG emissions*.

The intensive use and poor management of natural resources – including the occupation of new lands by fuel crops, particularly virgin land – are associated with deforestation and lead to biodiversity losses. In India, Sri Lanka and Thailand, wood harvesting by poor populations has resulted in deforestation around roads, towns and cities. In the Sudan, an estimated 400 km radius around Khartoum has been cleared for fuelwood. Biodiversity is also lost when large-scale monocrops are grown for energy purposes, even when non-forest land is used. The loss of pastoral lifestyles associated with shrinking grasslands, and the loss of feed production for domestic and wild herbivores on these lands, could have significant negative economic and social impacts (UN-Energy, 2007).

As well as its effects on biodiversity, deforestation also has implications for climate change. The burning of forest and peat to open new lands for biofuel plantations increases CO₂ emissions. Soya and sugar cane plantations in Brazil and palm-oil in Indonesia are examples of developments that have caused deforestation, which is a major cause of GHG emissions in these countries (GRAIN, 2007). These facts imply that countries need to assess the GHG emissions associated with various bioenergy alternatives carefully; such emissions must be considered in terms of a full life cycle. The potential for bioenergy projects to reduce GHG emissions has already been

recognized. Such projects are well represented in the current global CDM pipeline, which will help to overcome some of the financial barriers to biofuels development.

Although the prices of oil and other fossil fuels are very high, and likely to rise in the future, developing countries need to access the *risks associated with investments in bioenergy* very carefully. Many of the investments in biofuels made in the 1980s (IBDF, 1979; Tomaselli, 1982) collapsed shortly after oil prices returned to their original levels, but the situation has since changed, as new elements such as global warming have become more relevant.

Many new investments in biofuels still depend on subsidies and new technology developments to be feasible. Developing countries often have limited finances and other priorities, so a full assessment of the risks and the identification of ways of maximizing the benefits from investments in bioenergy are fundamental. One option for this is the phased approach discussed in the section on Opportunities for developing countries in chapter 5.

6. Conclusions and recommendations

Energy consumption will continue to grow, and fossil fuel will continue to be the main source of energy over the next few decades, in spite of concerns about climate change and energy security and the efforts of several countries to develop alternatives. Biomass is an important source for energy generation in several developing countries, but its use is normally limited to heating and cooking, with few developments in power generation and other applications.

Developing countries' policies and programmes to further bioenergy alternatives are still in their early stages and focus on liquid fuels, especially for the transport sector. These policies and programmes are also generally limited in terms of scope, with more attention on regulatory measures than on investments in other relevant areas, such as R&D, market liberalization, information and training. Furthermore, several developing countries' forests have enormous potential to produce biomass for energy with relatively low investments and risks, but this potential is not properly reflected in national energy development strategies.

Large bioenergy projects require extensive land areas and can affect food security, biodiversity, the wood processing industry and the availability of construction and other wood products on the market. To mitigate these eventual impacts, countries need to regulate land uses and take into consideration national interests and other policies, such as the involvement of all stakeholders, when implementing strategies to develop bioenergy. In a national strategy, it is also important to consider the potential efficiency gains from using existing forest and agriculture residues, and to take advantage of the often extensive degraded lands available. Planting trees also helps to combat erosion and restore ecosystems, for example.

Developing countries tend to have limited human and financial resources, so bioenergy development should first explore opportunities based on already available biomass and proven technology, rather than investing in dedicated fuel crops and the development of new technologies.

Synergies between the forest industry and energy generation provide opportunities for both sectors. Integrating energy generation into forest industrial operations is a competitive way of reducing risks, increasing profitability and improving forest management. It also strengthens energy security and contributes to climate change mitigation. This should be a priority for exploration by developing countries investing in bioenergy.

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