


Forests and energy

Key issues

DRAFT FOR COMMENTS




Forests and energy

Key issues

DRAFT FOR COMMENTS

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2007

Comments on this draft are welcome; please direct them to:
Wulf.Killmann@fao.org

Contents

Preface

Forests and energy are at the centre of the global debate on climate change. This document is intended to bring together in one place some of the most important trends in both the forest and energy sectors to help enlighten this debate. It represents the first step in a major analysis of the impacts of new energy trends on forests. The document consolidates and draws upon two other, more comprehensive studies commissioned by FAO in 2007:

- *Forests and energy in developing countries,* by Ivan Tomaselli, Brazil;
- *Forests and energy in OECD countries,* by Warren Mabee and Jack Saddler, Canada.

Both of these publications are available in English only on the FAO Web site, www.fao.org/forestry.

Throughout history, wood was the most important source of energy for human beings until petroleum became widely available during the last 100 years. In many of the world's poorest countries, wood remains the most important source of energy for heating and cooking. In this study, we look into the future and find that wood is once again likely to emerge as a very important source of energy in all countries as the twenty-first century progresses.

Bioenergy from wood and from agricultural sources regains its earlier importance. Agricultural and forest crops play a particular role in modern bioenergy generation as sources of liquid biofuels. While fossil fuels are likely to remain the dominant source of energy for decades, a long-term and gradual partial conversion from fossil fuels to solid and liquid biofuels is an increasingly likely scenario for many countries. Will these trends have an impact on food security? Will these trends result in more or less forest in the future?

This document explores these questions and more as a contribution to informed policy discussions. We welcome your comments.

Wulf Killmann
Director, Forest Products and Industries Division
FAO Forestry Department

1. Introduction

Sources of energy used by humans for cooking, heating, transportation, and power generation can be divided into two broad categories:

- Renewable energy sources include biomass, sunlight, wind, tides, geothermal heat, and hydropower.
- Non-renewable sources include fossil fuels (coal, gas, oil) and nuclear energy.

The world's attention is increasingly focused on alternative forms of energy. Fossil fuels are becoming less available and more costly, and many countries are looking for ways to reduce their dependence on imported oil. The demand for energy continues to grow with the expanding global economy. Forests are increasingly in the middle of the debate about energy for several reasons:

- Throughout history, wood has been one of the main sources of energy. Today, woodfuels are increasing in importance in all regions of the world. This trend may increase dramatically in the next decade when new technologies are expected to improve the cost efficiency for converting cellulose into liquid biofuel.
- Agricultural crops are increasingly being used for fuel. This trend raises concerns about food security, as agricultural lands are used to grow biofuels in an increasing number of countries. At the same time, there are growing pressures to convert forests to grow instead crops other than trees to be used for fuel.
- The debate about the causes of climate change is to a large extent a debate about the burning of fossil fuels to generate energy. The role of forests as carbon sinks, the potential to increase the use of wood for energy, and the impacts of climate change on forest health, will continue to gain attention as the world struggles to mitigate and adapt to climate change.

The situation is complex. Proponents of bioenergy argue that it is a renewable energy source with lower environmental impact than fossil fuels; carbon is absorbed when new plants or trees replace those that are burned for energy. However, significant amounts of energy are required to grow, harvest, and transport biofuels before they are converted to energy; hence, bioenergy is not totally "carbon neutral." Biodiversity may be reduced if natural forests are replaced by crops to produce liquid biofuels.

Forests and energy play a critical role in climate change. About 18 percent of global carbon emissions are related to deforestation and land use change. Forests help to mitigate climate change by absorbing and storing carbon; but forests are also affected by climate change, and their ability to adapt is a major topic of concern. Climate change – together with the increasing prices of fossil fuels and the issue of energy supply security – is the main driving force for investments in renewable energy sources and in more efficient energy utilization, especially in transport and industrial processes.

Forests as a source of energy are important in many countries, especially in rural areas in the least developed countries, where the availability of woodfuel is literally a human necessity for survival.

There is a huge variation in the role of wood as a source of energy in different regions of the world. Developing countries rely heavily on wood as a source of energy, especially for heating and cooking, and most of them are struggling to maintain their forests in the face of increasing populations and weak economies. Industrialized countries and several large rapidly growing developing countries use a vast majority of the world's fossil fuels; but these same countries have generally been able to stabilize or increase their forest area.

As the dynamics of energy use continue to evolve in combination with climate change, the consequences for the world's forests will be profound. Demand for energy is clearly one of the most critical issues facing the forest sector in the twenty-first century.

Bioenergy includes all energy derived from biomass – from living organisms of biological origin. The sources of bioenergy are also called biofuels. Bioenergy is considered renewable since it is based on the carbon cycle; new trees or other plants can replace those that have been converted to energy.

Biofuels can be divided into four categories:

- woodfuels;
- agrofuels (derived from non-woody biomass);
- municipal waste;
- fisheries by-products.

This paper focuses on the two major categories: woodfuels and agrofuels.

Biofuels include solid, liquid or gas fuels derived from biomass. Liquid biofuels are gaining increasing attention as an alternative to fossil fuels.

Liquid biofuels are not new. Nikolaus Otto, Rudolf Diesel, and Henry Ford – pioneers of modern transportation – designed their engines and vehicles to run on biofuels. Petroleum became the dominant fuel for transportation only after it was discovered in large quantities in the twentieth century and became the cheapest form of energy, first in the United States and subsequently throughout the industrial world.

Some proponents of biofuels claim that they are carbon neutral. This implies that the carbon released when the fuel is burned is replaced by the carbon absorbed by the growth of new plants that replace the old. However, energy is used to grow, harvest, and transport crops and biofuels. Total carbon neutrality is probably not possible to achieve.

In the world today, the main sources of energy vary dramatically from one region to the next. The most highly developed industrialized countries tend to rely heavily on non-renewable sources of energy, especially fossil fuels. The least developed countries tend to rely heavily on renewable sources of energy, especially wood, for heating and cooking; but they generally use fossil fuels for power and transport. Patterns of energy use are changing rapidly in countries experiencing high rates of economic growth, such as China, Brazil and India.

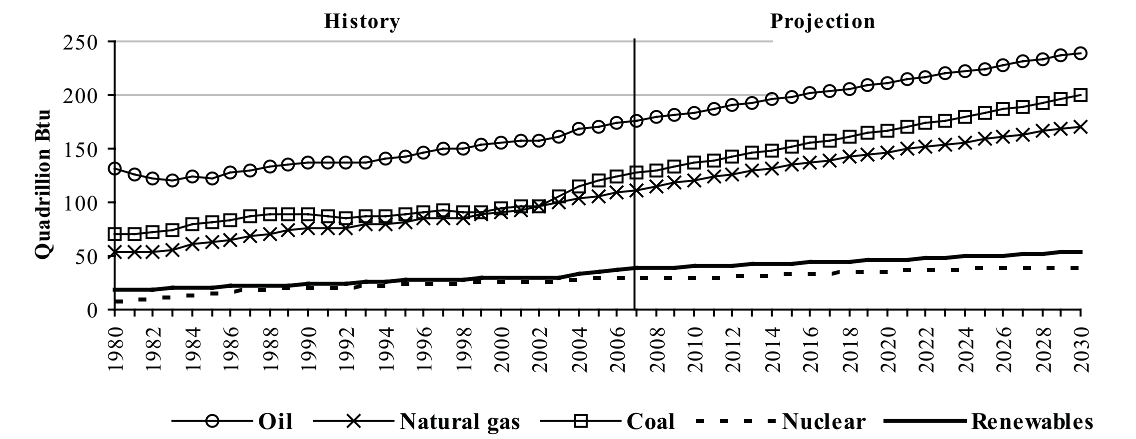
2. Energy trends

Global consumption of marketed energy from all sources is expected to continue to increase over the coming decades (Figure 1).

Developing economies are especially sensitive to fluctuations in global energy supply and demand. The International Energy Agency (IEA) points out that a US$10 increase in the price of oil 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).

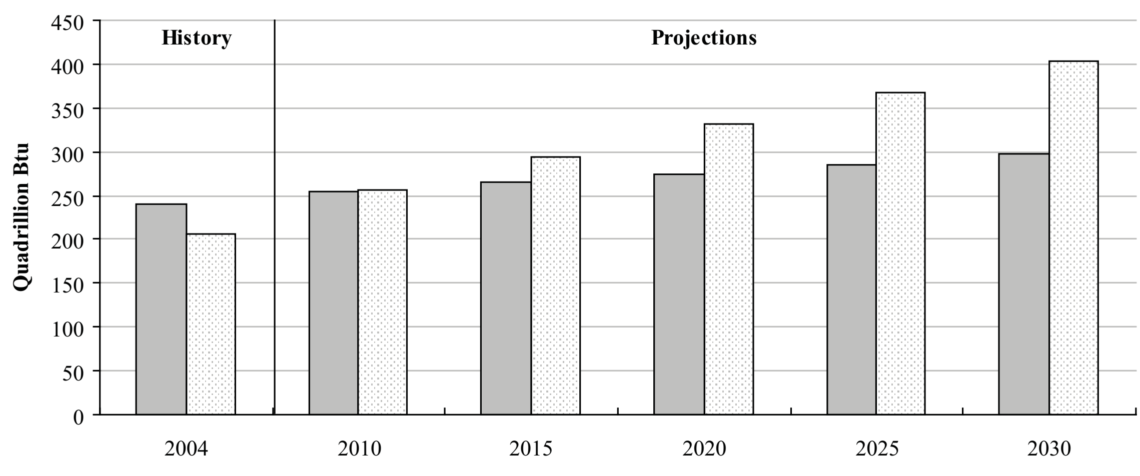
The largest increase in energy demand over the coming decades will take place in developing countries as a result of relatively high rates of economic growth and population increases (EIA, 2007). Currently, about 55 percent of global energy consumption occurs in industrialized countries, but this relative share is expected to decline in the future (Figure 2).

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



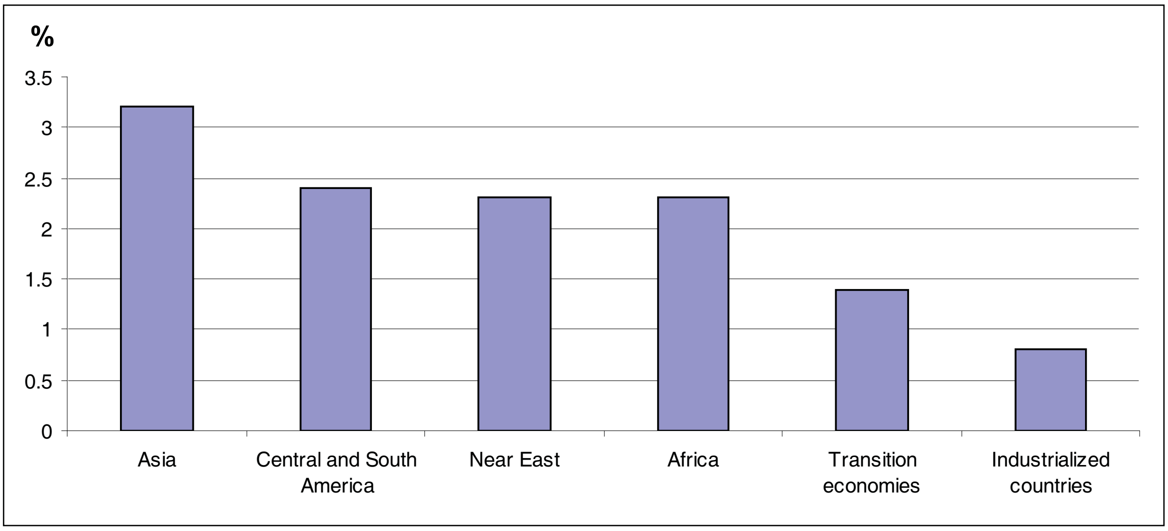
Source: EIA, 2007

2
Marketed energy use industrialized and non-industrialized countries, 2004 to 2030



Source: EIA, 2007

3
Projected increase in energy consumption to 2030



Energy consumption in developing countries is projected to grow at an average annual rate of 2.6 percent from 2004 to 2030. In industrialized countries, where national economies are mature and population growth is expected to be relatively low, the demand for energy is projected to grow at the much lower rate of 0.8 percent per year. Energy consumption in developing regions is projected to surpass that in industrialized regions by 2010; by 2030 developing countries will account for 57 percent of global energy consumption.

Much of the increase in energy demand will be a result of fast economic growth in Asian countries, especially China and India. Energy demand in the developing countries of Asia is projected to grow at an average rate of 3.2 percent per year, far higher than any other region. 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 developing countries.

Energy consumption in developing countries in other regions is expected to grow at a slower pace than in Asia, but still more rapidly than the global average (Figure 3).

Non-renewable sources

Oil and other petroleum-based products are expected to continue to provide the largest share of world energy in the near future, but with increases in petroleum prices foreseen over the coming years, it is projected that their contribution to total energy consumption will fall from 38 percent in 2004 to 34 percent in 2030.

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 CO_2 emissions, while one-third of CO_2 emissions comes from vehicles used to transport goods and people. Since 1990, transport has recorded the fastest increases in greenhouse gas (GHG) emissions in the European Union (EU), Japan and the United States.

Renewable sources

The use of hydroelectricity and other renewable energy for power is expected to continue to expand. Based on United States Energy Information Administration (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.

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).

BOX 1
Biofuels for transport in Brazil

Although liquid biofuels currently contribute only about 1 percent of the consumption of transport fuels in the world, Brazil is a notable exception. Brazil launched a national biofuel programme during the first global oil crisis in 1975, leading to the production of ethanol on a large scale from domestic sugar supplies. More than 90 percent of all cars produced and sold in Brazil are "flex", equipped with a motor that can run on ethanol, petrol or mixtures. Brazil has recently launched a global campaign to promote biofuels as a viable alternative to fossil fuels for transport.

Although heating and cooking will remain the principal uses of renewable fuels, 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.

Currently, less than 1 percent of fuels used for transport are renewable (see Box 1); according to projections, this share will rise to 3 percent over the next 25 years. However, the impact of these changes on global energy consumption will be relatively small.

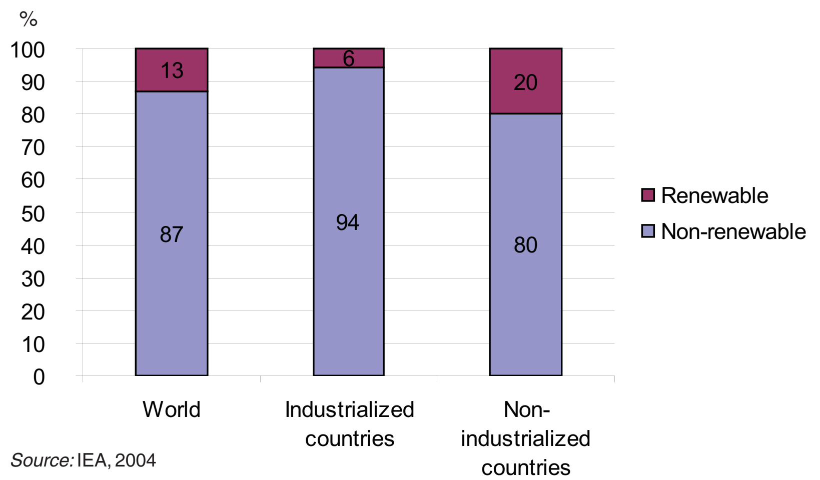
Renewable energy makes up a greater proportion of total energy supplies in developing than in developed countries (Figure 4). About three-quarters of renewable energy is consumed in developing countries, where most renewable energy production is based on the use of traditional biomass and hydropower. Industrialized countries account for 23 percent of the total renewable energy consumed worldwide, and the transition economies for 3 percent (Figure 5).

The two regions where renewable energy is the most significant are Africa and Latin America. In Africa, this is due to the high use of woodfuel for heating and cooking. In Latin America, this is due to the high use of renewables in Brazil, where 45 percent of all energy consumed is based on renewables – hydroelectricity, wood, and sugar-cane ethanol. Brazil consumes about 90 million tonnes of wood per year for energy generation, roughly the same as the consumption of sugar-cane ethanol. A large portion of it is converted to charcoal for steel smelting.

Almost 90 percent of the energy derived from biomass is used by developing countries. However, in some developing countries the relative importance of traditional biomass for energy is expected to decline over the next few decades due to reduced availability of fuelwood, increased per capita incomes and increasing urbanization. These factors promote the replacement of traditional biomass by fossil fuels.

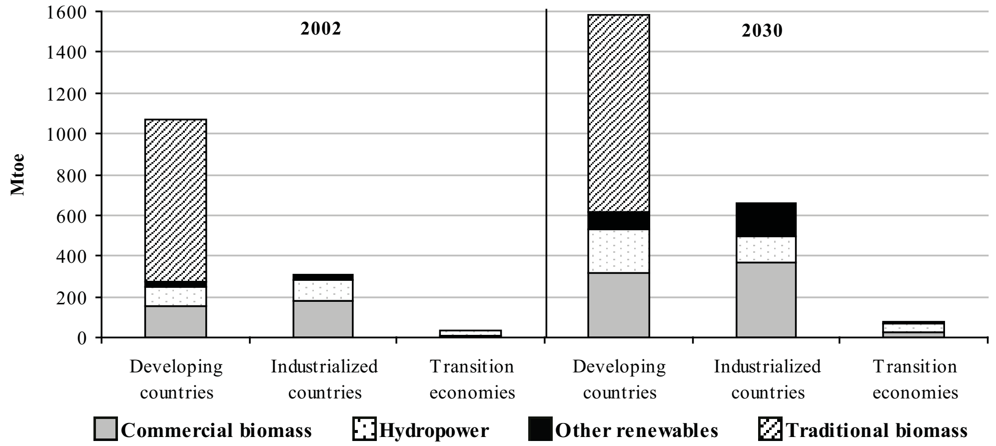
Figure 6 shows the trend of bioenergy use in 13 countries that consume the largest amounts of energy in the world – the so-called "G-8 + 5" countries. Bioenergy is increasing in most of

4
Renewable and non-renewable energy consumption (%)



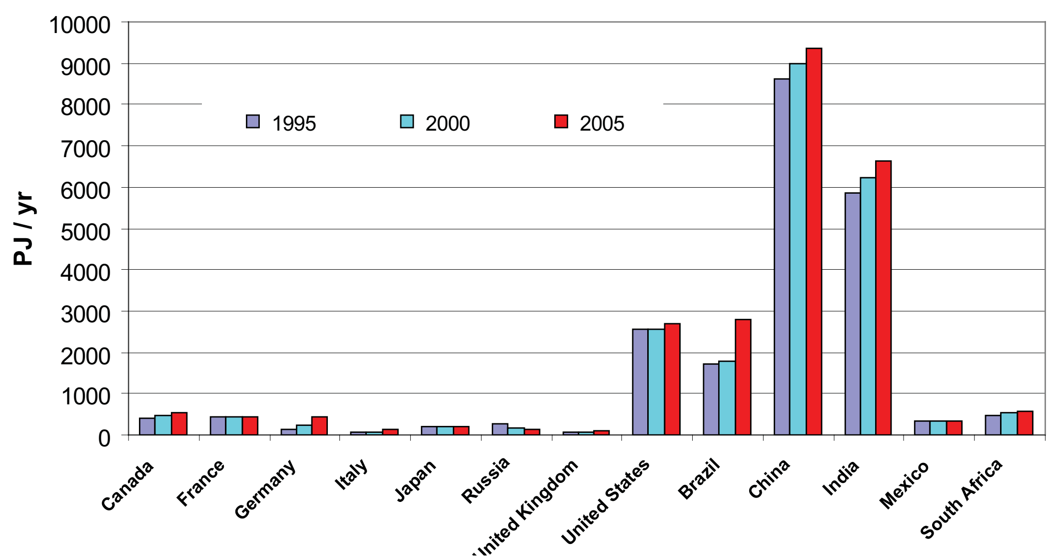
Source: IEA, 2004

5
World renewable energy consumption by region



Source: IEA, 2004

6
Total primary energy supply (TPES) bioenergy of G8 + 5 countries



these countries, with the notable exception of the Russian Federation where the availability of fossil fuels is increasing.

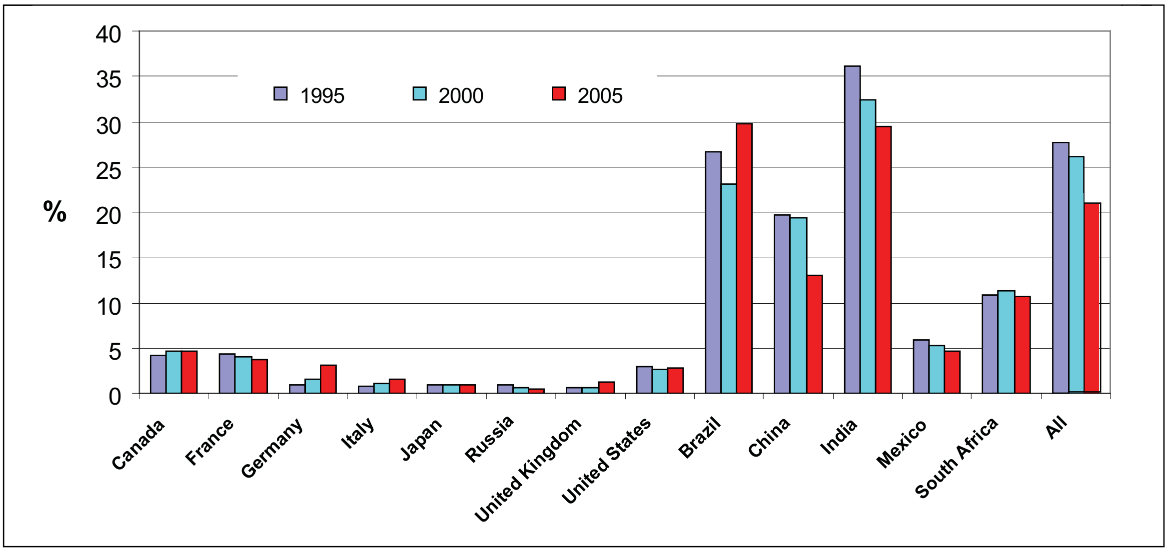
Figure 7 compares the relative use of biofuels as a percentage of total energy consumption in the G8 + 5 countries, where the impact of government policies is clearly seen. Bioenergy increased as a percentage of total energy use between 2000 and 2005 in Germany, Italy, the United Kingdom, the USA and Brazil, all of which provided economic incentives for biofuels. However, the relative use of fossil fuels declined in countries such as China and India where high rates of economic growth outpaced the impacts of rising fossil fuel prices.

Wood-based energy

Historically, wood has been the most important biofuel. Wood has been used for cooking and heating since the discovery of fire. Today, about half the world's annual harvest of roundwood, or about 1.8 billion cubic metres per year, is used for energy.

Developing countries account for almost 90 percent of the world's woodfuel production. Over the last 15 years global consumption of woodfuel has remained relatively stable, about

7
Percent of biofuels to all fuels in the G8 + 5 countries



1.8 billion cubic metres. Wood is still the primary source of energy for cooking and heating in developing countries, where about 70 percent of energy is based on burning biomass. In Africa, almost 90 percent of wood removals are used for fuel, compared with less than 40 percent in the world at large.

3. Bioenergy production

Solid woodfuels

Open fires make inefficient use of the intrinsic energy of wood, converting only about 5 percent of the potential energy. Traditional wood stoves (Anon., 1784; Werner, 1797) increased this efficiency to about 36 percent, and charcoal-based systems are between 44 and 80 percent efficient, depending on the furnace design and charcoal production methods. For residential use, the modern wood pellet stove delivers about 80 percent efficiency per tonne of feedstock (raw material for energy production) (Mabee and Roy, 2001; Karlsson and Gustavsson, 2003).

For industrial-scale bioenergy production, a number of combined heat and power (CHP) systems are in use or under development. These include power boilers for heat recovery, CHP systems for the production of both heat and electrical power, and gasifier systems for advanced energy recovery.

Steam-turbine power boilers, designed to work primarily with bark, can be added to sawmills as an alternative to beehive burners and other forms of waste disposal. Heat from power boilers can be used to generate steam, which can be used in turn to meet process requirements or be directed to turbines for electricity generation.

Recovery boilers are used in a similar way in pulp and paper mills, to recycle black liquor (a by-product derived from pulp and paper making and used to generate energy for these industries) and recover pulping chemicals, as well as producing steam to drive the pulping process. However, the historically low cost of fossil fuels has not provided much incentive for installing electrical generation capacity within mills. The efficiency of a steam-turbine power boiler is generally about 40 percent.

CHP facilities can use the steam to supply other industrial processes or support district heating grids for residential, institutional or industrial facilities. The recovery of both heat and power from the process is referred to as cogeneration, and can significantly increase the efficiency of operations. When the most recent technological advances are used and flue-gas recovery and recycling incorporated, efficiency can rise to between 70 and 80 percent (Karlsson and Gustavsson, 2003).

Wood pellets are originally produced from wood waste such as sawdust and shavings, rather than whole logs, and thus should be viewed as an integrated part of forest product manufacturing. The raw material is dried, mechanically fractioned to size and extruded under intense pressure into pellets. During the process, the raw material is densified approximately 3.7 times. The final net energy efficiency (ratio of energy in to energy out) of wood pellets ranges between 8 and 11.

Agrofuels

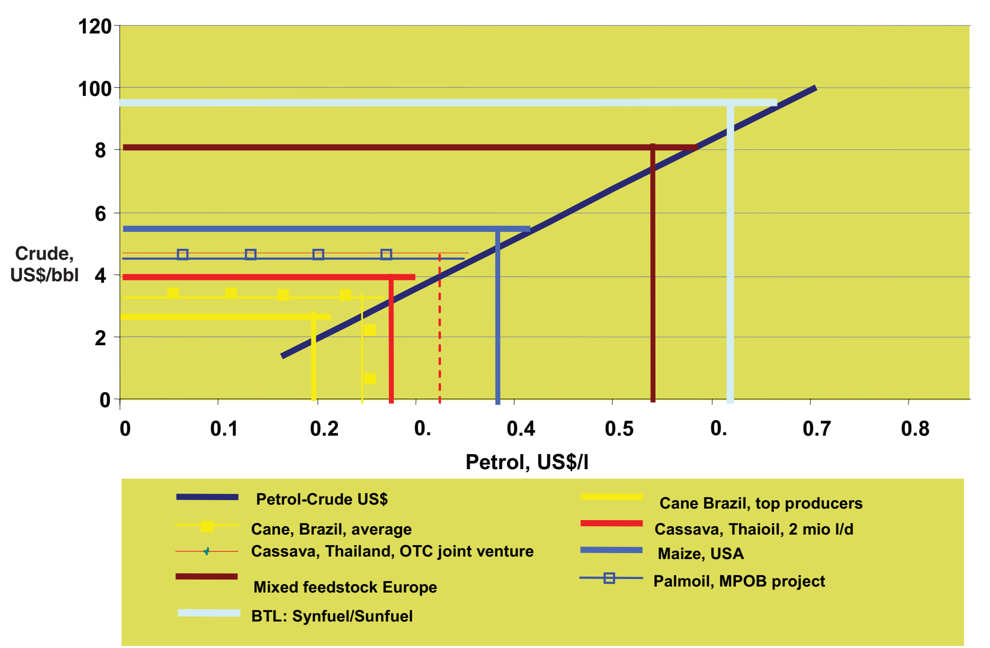
Agricultural residues such as bagasse (the residue from sugar-cane stalks), cotton stalks and rice husks have long been used for conversion into energy.

High oil prices have led to increased interest in liquid biofuels, especially from agricultural crops. The first generation of cereal-based liquid biofuels include sugar- and starch-based bioethanol, and oilseed- and waste oil-based biodiesel. In temperate regions, rapeseed, corn or other cereals are used as feedstock. In tropical regions, cane sugar, palm oil, and, to a lesser degree, soya and cassava are used.

Throughout the world, oilseed crop production is more widespread than sugar crops. Production of oilseed crops requires optimal soil and growing conditions, and not every site is suitable. This may limit increases in oilseed crop production; it may also result in the conversion of forest land that is suitable for oilseed production.

Other oilseed plants, such as *Jatropha* spp., are being explored as a feedstock for biodiesel production. *Jatropha* is a genus of more than 100 species including shrubs and trees, originating

8
Competitiveness by feedstock



Source: FAO, 2006c

in the Caribbean and now found throughout the tropics. The seeds of *Jatropha curcas* produce oil that has been used for biodiesel fuel in the Philippines and India. One hectare of *Jatropha curcas* can produce up to 2 000 liters of biofuel. It can also be intercropped with food crops. The plant is hardy, grows well on marginal lands and can be used to restore degraded lands. These characteristics suggest that *Jatropha curcas* production, if carefully managed, might be increased without directly competing with natural forests or with high-value agriculture lands used for food production.

As Figure 8 suggests, sugar cane is the most economic agricultural feedstock for liquid biofuel, while maize and other cereal and oilseed crops from the Northern Hemisphere are less competitive under market conditions.

Liquid cellulosic biofuels

A second generation of technologies under development may allow the use of cellulosic feedstocks, including both agricultural residues and wood, to produce liquid biofuels for transport. It is generally anticipated that the technology for efficient conversion of cellulose to liquid biofuels will be widely available within ten years. Bioethanol is currently the cellulosic liquid biofuel closest to commercialization.

Agricultural residues. Bagasse (the lignocellulosic component of the sugar-cane stalk) and residues from cereal agriculture can also be used as feedstocks to generate bioethanol. Bowyer and Stockmann (2001) suggested that after accounting for the factors of soil conservation, livestock feed and seasonal variation, an average of only 15 percent of total residue production would be available for industrial energy generation. Yet as bioenergy production increases, agricultural residues may become more important as agrofuels, and their availability may increase through better management practices. In most countries, residue availability is dominated by species other than maize, including wheat, barley, rice and rye. Agricultural residues from production of these cereals are technically suitable for cellulosic liquid biofuel production.

Figure 9 suggests that the cost of producing ethanol from lignocellulose is currently higher than that from cereal feedstocks, but that the potential for reducing production costs in the future is much greater for lignocellulosic ethanol.

Wood. Today, only a small proportion of liquid biofuels produced for transport are forest-based, but the development of an economically viable process for producing cellulosic liquid biofuels could lead to the widespread use of forest biomass in the power and transport sectors.

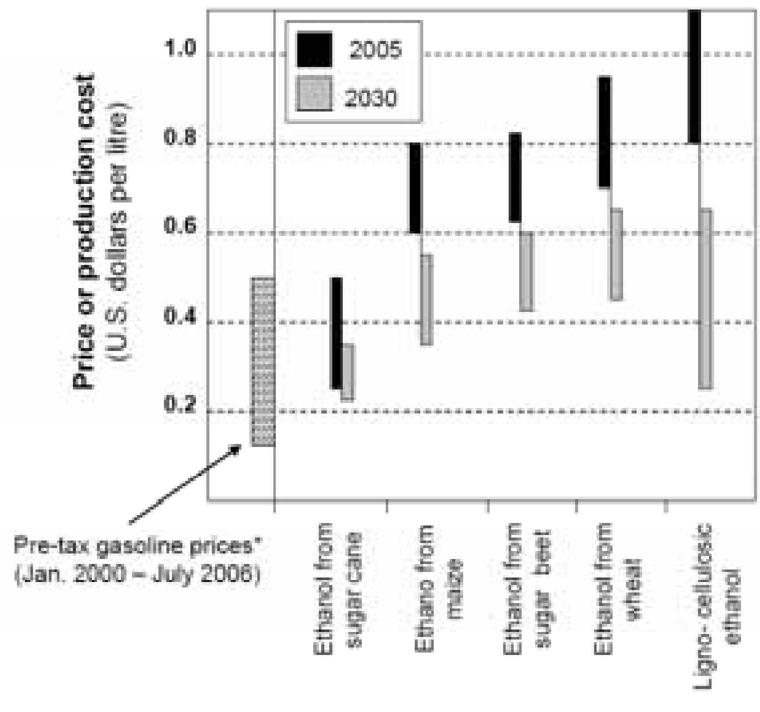
Biorefineries might use two distinct technologies to produce cellulosic liquid biofuels from wood: thermochemical and biological processes.

Thermochemical conversion can liquefy or gasify woodfuels, collect the chemical components generated and reassemble them into fuels. It is likely that the overall energy efficiency would rival the best existing small- and large-scale bioenergy processes.

Bioconversion uses biological agents to deconstruct the lignocellulose components of the feedstocks. It essentially blends pulp and paper technology with the commercial biotechnology processes used in the agricultural products sector. Bioethanol, the primary output from bioconversion, may be readily blended with petrol or used on its own.

Studies suggest that bioethanol produced from maize represents only a slight improvement in energy efficiency over petroleum, while bioethanol produced from wood can improve energy efficiency by up to four times (NRDC, 2006). Thus if technological developments make it more efficient and at least as economical to produce liquid biofuels from wood rather than from agricultural crops, the result would be reduced competition with food production, an increase in energy efficiency and improved overall energy balance. This could result in incentives to expand forests. On the other hand, as with other demands for forest products, if the new technologies are not properly managed, they could also result in increased deforestation.

9
Current and future ethanol production costs



* Based on monthly average import prices for crude oil into the IEA region, crude oil import prices varied between $20 and $70 per barrel in this period.

Note: Cost estimates exclude from consideration subsidies to crops or to the biofuel itself.

Source: Adapted from IEA (2006), Figure 14.7.

BOX 2
Greenhouse gas emissions associated with bioenergy production

Cellulosic liquid biofuel production could result in significant reductions in GHG emissions compared with liquid biofuel production from agricultural crops.

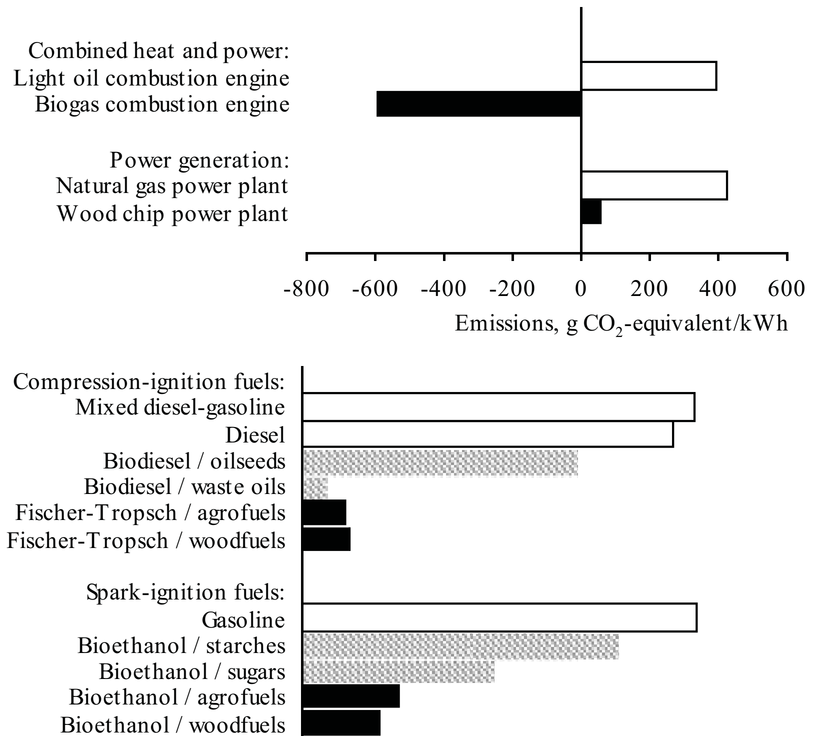
Spitzer and Jungmeier (2006) found that heat production from a combined cycle power plant operating on wood chips produced 60 g of CO_2-equivalent (CO_2-e) for each kilowatt of energy produced (Figure 10). A similar plant using natural gas produced about 427 g of CO_2-e/kWh. Emissions from a CHP facility operating on biogas were found to be -603 g of CO_2-e/kWh, assuming one-third electricity and two-thirds power generation.

This suggests that the CHP plant has lower emissions. A conventional light oil combustion engine produces about 391 g of CO_2-e/kWh (assuming one-third electricity and two-thirds power generation). By substituting emissions, the fuel produces an overall negative emission (VIEWLS, 2005).

Similar results were obtained in other studies, summarized in Figure 11, where ethanol from sugar cane in Brazil was found to result in the largest net decrease in GHG emissions compared with traditional fossil fuel sources, closely followed by ethanol from cellulosic feedstocks.

Although it can be argued that woodfuels from sustainably managed forests are carbon neutral, there is concern about the possible increase in air pollution if wood combustion expands. In particular, wood combustion in installations with insufficient filters or incomplete combustion releases fine particulates that are an acknowledged health hazard. An increase in wood combustion without corresponding upgrades of technology – particularly in

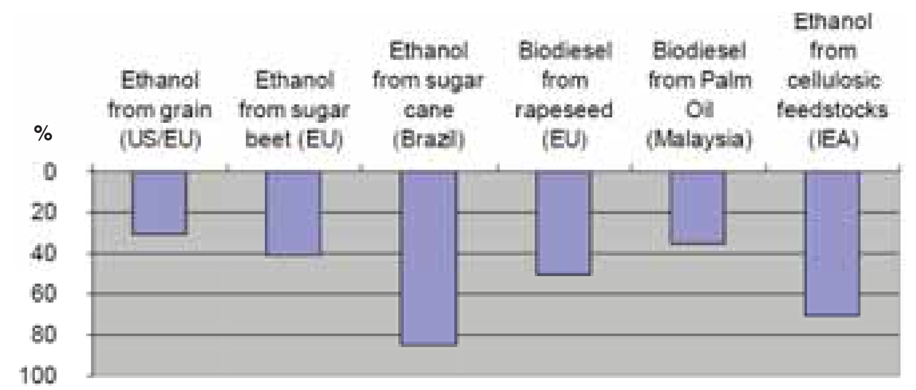
10
Comparison of GHG emissions of bioenergy (heat and CHP generation), biofuels and conventional fuels, using advanced technologies



Source: Spitzer and Jungmeier, 2006; VIEWLS, 2005 households, where inefficient fireplaces and stoves are common – could result in increased particle emissions, with consequential health risks. Combustion efficiency as a way of reducing particulate emissions should be considered during the evolution of wood energy policy. As increased biomass combustion has major consequences, a holistic approach is necessary when setting targets and policies to combat climate change.

These findings suggest that wood energy can offer significant improvements in the reduction of GHG emissions compared with fossil fuel options when heat and power generation are considered. Cellulosic liquid biofuel technologies show improved performance over cereal-based liquid biofuels or petroleum alternatives for the transport sector.

11
Range of estimated GHG reductions from different sources



Source: IEA, 2005 and EMPA (biodiesel from Palm oil). Note: Reduction in well-to-wheels CO_2-equivalent GHG emissions per kilometre

4. Bioenergy and wood supply

The availability of wood, including its potential as a biofuel to substitute for oil in the future, is unevenly distributed throughout the world (Figure 12). The Global Forest Resources Assessment 2005 (FRA 2005) (FAO, 2006a) indicates that total forest growing stock worldwide was 434 billion cubic metres in 2005, of which 202 billion cubic metres could be considered commercial growing stock.

Global industrial roundwood production was about 1.7 billion cubic metres in 2005, compared with fuelwood production of approximately 1.8 billion cubic metres (FAO, 2007c). About 65 percent of global industrial roundwood was produced in industrialized countries, compared with only about 13 percent of fuelwood. The largest producers of fuelwood are India (306 million cubic metres), China (191 million cubic metres) and Brazil (138 million cubic metres). Production of fuelwood is significant in only a few industrialized countries, primarily the United States and Mexico.

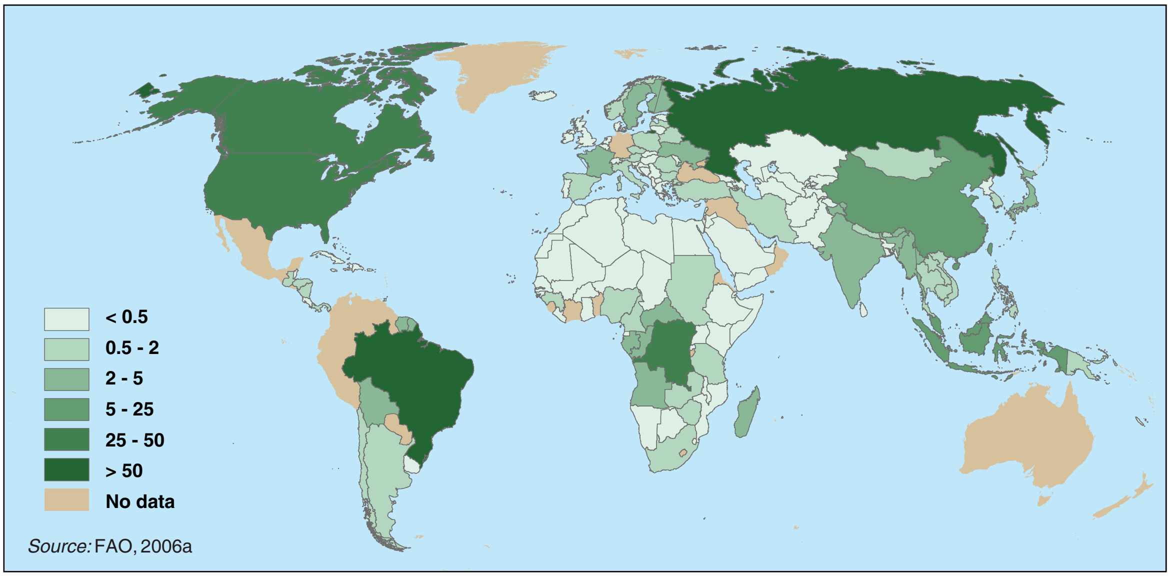
Imports and exports of industrial roundwood reached about 130 million cubic metres globally in 2005, compared with fuelwood at 3.6 million cubic metres (FAO, 2007c). Trade in fuelwood has increased slowly since 1961, when 1.9 million cubic metres was imported and 1.6 million cubic metres exported worldwide. These figures indicate that the vast majority of fuelwood is still produced and consumed locally. The fact that fuelwood is mainly used in private households and is often traded informally acts as a barrier to the collection of good country-level data.

Future scenarios

Global scenarios describing industrial wood fibre supply and demand have been created based on regional and global outlook studies on forest fibre availability produced by FAO, the International Institute for Applied Systems Analysis's (IIASA) (Obersteiner *et al.*, 2006) and the United Nations Environment Programme (UNEP) (Malhi, Meir and Grace, 1999). By comparing supply and demand outlooks, it was possible to estimate the "surplus fibre" available for non-traditional purposes, including woodfuels.

FAOSTAT statistics (FAO, 2007d) were used to estimate the availability of agrofuels, together with expert assessments of residue availability from different crop types, to create low, medium

12
Total growing stock (billion m³)



and high estimates of agricultural residue production for cereal crops. For 2010, arbitrary scenarios of 15, 30 and 50 percent residue recovery for bioenergy production were applied. For 2050, each of these figures was doubled, to reflect the potential increases in energy crop development.

Using these studies, the following three composite scenarios of sustainable biomass availability were assembled:

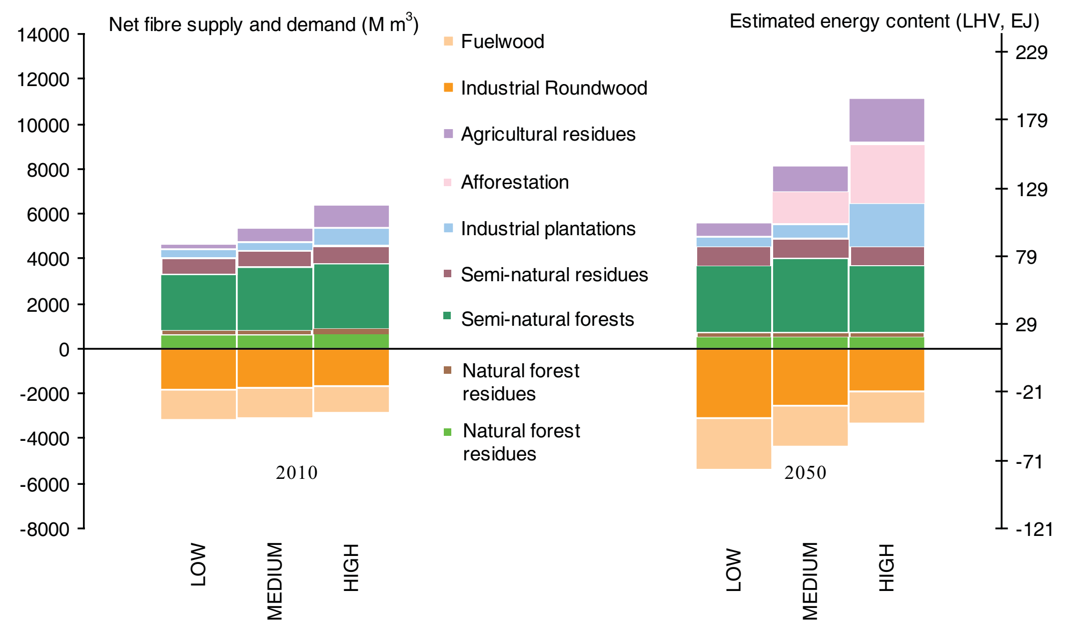
- ***The low scenario*** reflects increased economic competitiveness, with increased demand for forest products and a corresponding decrease in investment in long-term forestry. This results in increased deforestation rates and decreasing investment in silviculture, which is evident in lower yields and lower plantation establishment. A minimal recovery of cereal crop residues or establishment of agricultural energy crops is anticipated. Technology is assumed to remain at current efficiency levels.
- ***The medium scenario*** describes a business-as-usual case in which plantation establishment, deforestation and silvicultural yields continue as currently seen; forest product demand is also assumed to follow current trends. A medium recovery of cereal crop residues and/or establishment of agricultural energy crops is incorporated. Technology efficiency is assumed to advance to best practice levels.
- ***The high scenario*** reflects an environmental future in which green requirements drive more commercial forestry to industrial plantations, and an accelerating amount of natural forests are put under legal protection. Demand for forest products is expected to grow very little, as additional demand is offset by conservation and recycling strategies. Recovery of cereal crop residues and/or establishment of agricultural energy crops is incorporated at a high level. Technology efficiency is assumed to advance to best practice levels.

Potential additional biomass from afforestation is included in the medium and high scenarios for 2050. The potential new biomass from the collection of forest residues is incorporated in all scenarios. These scenarios are illustrated in Figure 13.

Based on current forest resources and trends in their use, the annual sustainable supply of forest biomass is estimated to range between 4.4 and 5.4 billion cubic metres (47.5 to 58.0 EJ) in 2010, and 5.0 to 6.5 billion cubic metres in 2050 (or 53.8 to 70.1 EJ based on a best practices approach achieving approximately 80 percent energy recovery).

Estimates of the contribution of natural (undisturbed) forests are relatively low, while semi-natural forests become most important in the business-as-usual case (the medium scenario).

13
Scenarios of global forest biomass supply and demand, 2010 and 2050



Source: Mabee and Saddler, 2007

Note: For the purpose of this figure, 1 bone-dry tonne of agricultural residue is assumed to be 1 m³. In practice, volumes range dramatically for agricultural residues.

In the strongly economic case and the green future (the low and high scenarios, respectively), semi-natural forests contribute less, because the forested land base available for wood supply is reduced as land is taken out of production and placed under protection. In a green future, the contribution of industrial plantations is significantly higher than in any other scenario.

More efficient utilization of wood

Estimated full recovery of forest residues could provide between 0.6 and 1.7 billion cubic metres of additional fibre annually by 2010, equivalent to between 6.6 and 17.8 EJ of energy; this could rise to between 0.6 and 2.2 billion cubic metres (6.5 to 23.2 EJ) by 2050. Additional afforestation of plantation species on previously non-forested land could provide between 1.4 and 2.7 billion cubic metres (15.2 to 28.6 EJ) annually by 2050. Finally, between 0.302 and 1.02 billion tonnes of cereal crop residues may be available in 2010 for bioenergy; this is equivalent to approximately 4.7 to 15.8 EJ of energy, using best practices. By 2050, depending on the rate of energy crop establishment, this might rise to between 604 million and 2.04 billion tonnes of biomass, or 9.4 to 31.6 EJ of energy.

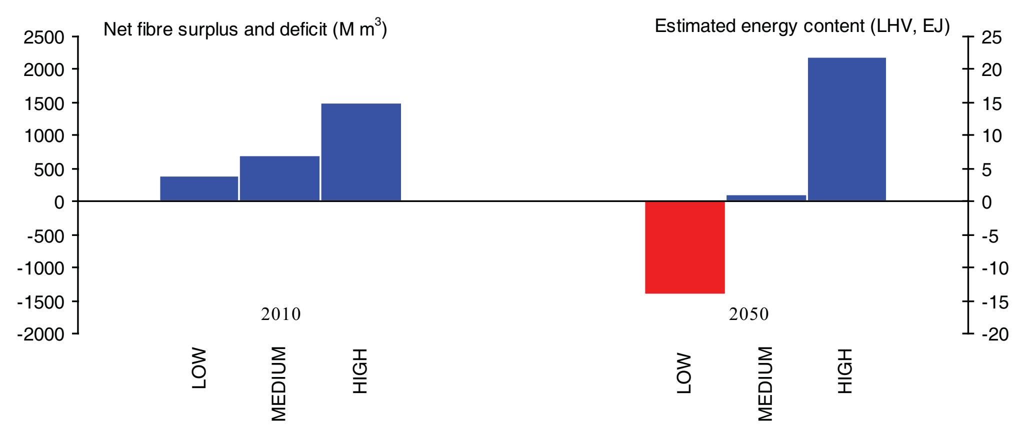
The potential surplus (or deficit) of forest biomass and the associated energy content based on best practices are shown in Figure 14.

Increased demand for wood energy in industrialized countries will have a significant impact on the amount of excess forest biomass that is available, taking between 10 and 25 percent of the estimated global surplus. In addition, there may be increases in demand from wood processing industries that are not considered in these scenarios. Finally, the global availability of fibre does not necessarily cover the demand in some regions.

The use of fuelwood becomes key in analysing the future availability of forest biomass for bioenergy purposes. Improvements in the efficiency of utilizing woodfuel could provide significant amounts of wood energy worldwide. By instituting a best practices approach to energy recovery (i.e. using CHP with flue gas recovery, or wood pellet stoves with approximately 80 percent efficient energy recovery per bone-dry tonne of biomass), the amount of energy available through woodfuel recovery increases dramatically, and the resource may be extended significantly.

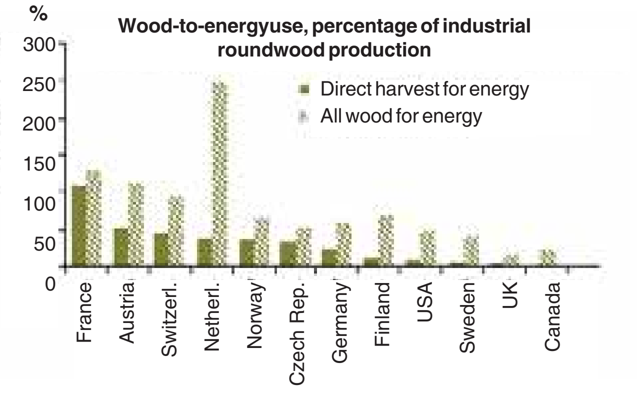
There is a perception that increases in forest-based bioenergy will have an impact on traditional processing industries. This is likely to occur; in some industrialized countries, removals of wood from the forest for bioenergy applications (Steierer *et al.,* 2007) already account for at least half of industrial roundwood production (FAO, 2007b). In other industrialized countries, the amount of wood used for bioenergy purposes is still small compared with industrial roundwood harvest. When residue recovery and post-consumer waste are factored in, however, the wood use for energy exceeds industrial roundwood production in several industrialized countries (Figure 15). The potential impacts of increasing biomass recovery from these forests could include nutrient scarcity, loss of biodiversity, changes to ecosystem function and differences in forest regeneration.

14
Net global fibre surplus/deficit and associated energy content, 2010 and 2050



Source: Mabee and Saddler, 2007

15
Wood-for-energy as percentage of industrial roundwood in selected industrialized countries



Sources: Steierer et al., 2007; FAO 2007b

Implications of increased use of wood energy

The major forest-product producing industrialized countries, including the United States, Canada, Sweden, Finland and Germany, do not yet use large amounts of wood for energy compared with industrial roundwood removals. Of these nations, the primary exporters of forest products are Canada, Sweden and Finland (FAO, 2007b). An increase in domestic wood energy use within these exporting nations could increase feedstock costs, which would have an impact on the ability of traditional forest product industries to compete on world markets (see Box 3).

In all cases, the cost of domestically produced traditional forest products could be expected to rise if the use of wood for bioenergy increases. However, as it is likely that non-renewable fuel prices would also rise (particularly given strong petroleum prices), these increases in cost might not have as great an impact as might otherwise be expected.

Ultimately, a move towards increased trade with developing countries might be expected, for feedstocks, traditional forest products and bioenergy products.

Increased bioenergy use in industrialized countries could have widespread effects around the world. Nations with large forest resources, including the Russian Federation and Brazil, might be expected to supply increased demand for bioenergy feedstocks, which could result in increased deforestation and forest loss. For example, in Brazil about 3 million hectares of forest was removed in an average year between 2000 and 2005, an annual deforestation rate of 0.6 percent (FAO 2006). Most of the deforested area is being used for non-sugar-cane agriculture, such as the raising and feeding of cattle. In Brazil approximately 190 000 ha of sugar-cane plantations are established every year, largely for bioethanol production in southern parts of the country (FAO, 2007d).

In Indonesia, an average of 1.8 million hectares of forests (or 2 percent of the forest cover) are disappearing annually. There is some evidence that bioenergy products destined for export contribute to this trend. The world's most significant oil-palm plantations are in Indonesia and Malaysia. In Indonesia, between 3.6 and 6.8 million hectares of land are under oil-palm plantations, which are increasing by 15.7 percent per year. The government is encouraging expansions of oil-palm, rubber and forest plantations. There are reports that the outputs from oil-palm plantations are being used for biodiesel production, primarily for use in Europe (Carrere, 2001; Colchester *et al.,* 2006).[1] This is an example of increasing bioenergy demand in industrialized countries affecting forests in developing countries.

The Roundtable on Sustainable Palm-Oil (RSPO) was established to monitor the impact of increasing palm-oil use, and has set an objective to develop criteria that define sustainable palm-oil production. RSPO principles and criteria were adopted in November 2005 for an initial period of two years, and will be reviewed through public consultation in November 2007 (RSPO, 2007).

[1] The claims in the Colchester *et al.* report should be read with caution given the lack of corroborating evidence from other sources, including FAO and the Oilworld.biz website; these sources indicate that between 300 000 and 500 000 ha of land is being converted to oil-palm annually. Approximately 17 to 27 percent of Indonesian deforestation (and 80 percent in Malaysia) may be explained by the establishment of oil-palm plantations.

BOX 3
Forest product prices and bioenergy

The long-term trend in real forest product prices since 1975 is downward, but with indications of an upward trend in the last few years. Figure 16 illustrates two examples of long-term pricing, using nominal (reported) prices for Austrian roundwood and Austrian pulpwood delivered to roadside (UNECE, 2007).[2] Real prices are reported in euros; nominal prices, in 2006 figures, were calculated using consumer price indices. Roundwood prices in Austria have remained fairly flat in nominal terms since 1975. With some fluctuations, prices at the roadside have remained at about €50 per cubic metre. Real prices, which take into account inflationary pressures, show that the value of wood has actually been declining on a per cubic metre basis, however.

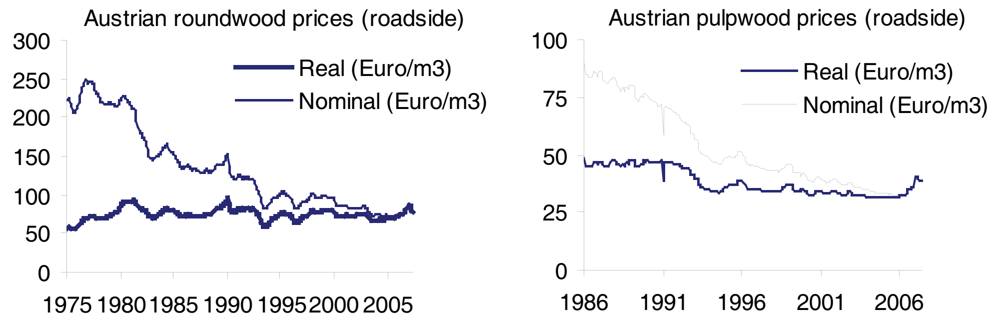
Figure 16 also shows that there is also a long-term decline in nominal pulp prices, which is exacerbated by inflationary pressures. The real value of these goods is less than half that of 1986.

Similar price trends have been reported in other European nations (for Sweden, see Hillring, 1997). It is difficult to determine the long-term global trend, owing to factors that include currency conversions, the impacts of national inflation rates, national tax regimes and data availability. The long-term trend in timber commodities markets has shown both positive and negative trends (Kellard and Wohar, 2006), which indicates that declining trends may break in favour of a more positive incline.

Long-term declining trends are supported by global estimates of the future forest products market (FAO, 1997b), which predict that the real prices of industrial roundwood, sawnwood and wood-based panels will change little until 2010, with those of newsprint, printing and writing paper decreasing slightly (FAO, 1997b; Trømborg, Buongiorno and Solberg, 2000). Over the past few years, however, real prices of forest products have been seen to rise around the world. These increases are evident in Austria, as Figure 16 shows.

Recent studies noted that prices for softwood sawlogs increased in most regions of North America and Europe in 2005/2006 (UNECE/FAO, 2006; 2007). Higher transportation costs were cited as a major reason for these increases. Pulpwood prices have also increased in these regions, again probably owing to increasing transportation costs and an improved pulp market. Prices for sawnwood and pulpwood are predicted to continue to rise over the next few years (UNECE/FAO, 2006).

16
Trends in Austrian wood prices



Source: UNECE, 2007

[2] Austria was chosen as an example because it has the longest price trends on file in the UNECE Price Database, as seen at www.unece.org/trade/timber/mis/price-stats.htm

Given existing trends in wood prices, several observations can be made:

- Even with rising wood value, the forest industry is experiencing lower returns today than in previous years. This will act as a barrier to reinvestment or to new companies entering the arena.
- The present value for wood, which is low compared with historical data, may be a factor in the decision to use wood in relatively low-value applications such as bioenergy, although compelling environmental or social arguments can also be made for this use.
- Increased competition for wood fibre as bioenergy opportunities are explored should support the recent trend towards higher wood prices. As wood prices rise, this trend may act to slow development of bioenergy opportunities over the medium to long term.
- Government policies can have a significant impact on wood prices. Subsidies for investments in "renewable energy," tax incentives, and tariffs are all having an impact on wood prices, especially in industrialized countries.

5. Bioenergy, food security and competition for land

Bioenergy and agriculture

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. Irrigation can greatly increase crop yields, but water can be a scarce resource. 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.

At the same time, forests in some countries have been replaced by crops intended to produce biofuels. This process could accelerate if there are large increases in the use of agrofuels as an energy source in the future. However, the dynamics could change dramatically if woody biomass becomes the biofuel of choice; could we face a future in which forests threaten farmland, rather than the other way around?

Food and energy have important links. Agriculture is itself an energy process; photosynthesis transforms solar energy into food energy for humans and animals (FAO, 2002). Agriculture also produces residues that can be used for energy generation. 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 processing and distribution. The energy consumption of agriculture in industrialized countries is 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. At the same time, bioenergy can enhance development. 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. Large areas of deforested and degraded land could benefit from forest plantations for energy generation (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 biomass production.

Even in heavily populated Asian countries, agroforestry, efficient energy conversion technologies and the use of agricultural wastes could make it possible to produce significant amounts of liquid biofuels. Latin America, much of Africa and some forest-rich countries in Asia have large areas that could be used for biomass production, but often in competition with forests. In such instances, economic development can conflict with biodiversity conservation, water protection and other environmental services rendered by forests. The absence of good land use planning and weak forest law compliance pose serious threats to sustainable forest management.

If prices of biofuel crops rise significantly, farmers will tend to convert food croplands to energy crops. In the short term, this could reduce food supply, and food prices will increase. However, farmers shift cultivation quite frequently, and crop decisions are based mainly on market prices and profitability. Higher food prices would increase the incentive to use land for 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, an increase in food prices, even if only transitory, would affect poor people, especially in developing countries (see Box 4).

Biomass production for bioenergy may strengthen livelihoods by offering new income sources and hence enhance food security. There are many variables which can determine if the expansion

BOX 4
Food prices and bioenergy

Rosegrant *et al*. (2005, 2006) studied potential impact of the growing demand for energy on real world food prices. Within an aggressive biofuel growth scenario (assuming that total biofuel consumption would rise between two- and tenfold in specific countries or regions around the world, including China, India, Brazil, the United States and the EU, and presuming that oil prices would stay high in real terms), they examined three cases (Table 1):

- continued focus on cereal-based liquid biofuels;
- new development shifting to wood-based liquid biofuels;
- increased use of cellulosic biofuels combined with improvements in agricultural practices.

It should be noted that these scenarios do not reflect the potential impacts of climate change on food productivity.

The authors estimated that in the first case, real food prices would rise significantly by 2020. However, offsetting new development with wood-based fuels could reduce these increases somewhat. Combining cellulosic biofuels with agricultural improvements could result in the lowest possible price increases. Each of these cases suggests higher real crop prices in the future.

It is clear that each of the three cases would entail higher average prices in the global food marketplace, although changes at the country level would vary. These results are confirmed by other models, notably an analysis by Schmidhuber (FAO, 2006c) which found that the extra demand for biofuel feedstocks has resulted in increased global agricultural commodity prices.

An increase in food prices would have an impact on food security, particularly in countries where food is scarce owing to poor growing conditions or other environmental factors. A price increase for food commodities would also increase incomes in rural areas, however, potentially reducing poverty in these regions. Increasing the proportion of wood-based biofuels could help decrease the expected rise in food prices, but some cost increases must be expected. It should be noted that, historically, real prices for food and agriculture have been declining, and a departure from this trend to meet biofuel demand may not be permanent (FAO, 2006c).

Table 1
Expected rises in commodity food prices in three cases under an aggressive biofuel growth screnario (% increase over 2005)

Commodity	Continued focus on cereal-based biofuels	Shift to wood-based biofuels	Wood-based biofuels + agricultural improvements
Cassava	135	89	54
Sugar beet	25	14	10
Sugar cane	66	49	43
Oilseeds	76	45	43
Maize	41	29	23
Wheat	30	21	16

Source: Rosegrant et al., 2006

of bioenergy has a net positive or a net negative impact on livelihoods. When small scale farmers have the opportunity to produce biomass independently or through outgrowing schemes, there may be net benefits. The harvesting of crops such as *Jatropha* seeds is labour intensive and can generate jobs and incomes for rural people. On the other hand, the harvesting of bioenergy crops such as sugar cane do not use much labour and provide relatively few jobs for the rural poor.

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.

Large-scale energy production 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 on one hand, but perhaps create smallholder opportunities on the other. Government measures to protect small farmers 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, a secure market for agricultural products, the provision of cheap local supplies of energy, and reductions of greenhouse gas emissions.

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 in agroforestry systems, and incorporating land conservation systems such as windbreaks and shelterbelts. 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 biofuels. 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 can help to promote food security through its positive macro-economic impacts.

Competition for land

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 an impact on forests. There could be an impact on food security, 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. Depending on the degree of expansion of the bioenergy crop(s) and the reduction of the forest 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.
- Wood produced from existing forests is diverted to the energy sector. This would have an impact on the management practices for native forests and plantations and would increase competition for resource among wood users. Wood available to the forest industry would decline and the costs of raw material increase.
- The efficiency of wood use is increased by optimizing industrial processes and using harvesting residues, mill residues, recovered/urban wood and other by-products to produce bioenergy. Significant amounts of energy could be generated, and the impacts would be minimized.

In a 2004 study based on IEA data, different agrofuels were compared in terms of the amount of arable land they require. To produce the same amount of energy, soybean requires almost 12 times as much arable land as sugar cane. Other potential biofuels fall somewhere between these two extremes. Corn, for example, requires twice as much land as sugar cane, while oil palms require about 30 percent more land. Even more strikingly, if the question is asked, "How much arable land would be required to replace 25 percent of the energy from fossil fuels with energy from biofuels?" the result would be 430 million hectares for sugar cane (17 percent of the world's arable land), and 5 billion hectares for soybean (200 percent of the world's arable land) (Fresco, 2006). The factors are such that it is not realistic to conceive of biofuels as totally replacing fossil fuels; biofuels need to be viewed as one potential source of energy that will always need to be used in combination with other energy sources.

6. Forests, energy and development

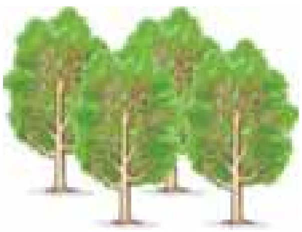
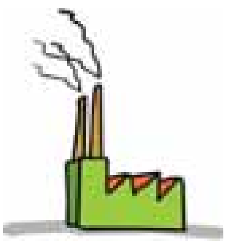
The increased use of wood energy produced with efficient technology is already competitive with fossil energy in many countries. As well as being economically attractive, wood energy can be a strategic option to increase energy security, which is particularly important in countries that have large forest areas, but that depend on energy imports.

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 17 provides general information on 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 16 suggests 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 could 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 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. Excess wood residues provide

17
Forest industry operations and wood residues

Operation	***Natural forest***	***Plantations***
Harvesting	 Logs (30–40%); Crown and rejects (60–70%)	 Logs (80–90%); Crown/small diameter and other rejects (10–20%)
Primary and secondary processing	 Final product (10-20%); Bark, Cutting, Sawdust, Shaving, Others (10–20%)	 Final product (30–40%); Bark, Cutting, Sawdust, Shaving, Others (40–50%)
Wood residues	80–90%	60–70%

Sources: ITTO, 2005; STCP Data Bank, adapted a good opportunity to produce energy. Proven combustion technology could be used, combined with simple steam machines for small-scale power production, or steam turbines for larger power plants (ITTO, 2005).

Table 2 suggests a considerable amount of energy is available from wood residues. In some countries, such as Cameroon, 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.

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. Efficient harvesting and transport technology can be used to collect this material and delivering it to power plants, in order to reduce costs, mitigate environmental impacts and produce competitive power.

Forest plantations dedicated to the production of wood for energy have existed in many countries for some time (NAS, 1980), so 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 decades. Significant investments have been made in plantation forests, mostly of fast-growing *Eucalyptus* spp., 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.

Clear and consistent policies, laws and best practice guidelines can help to balance the trade-offs among cultural, economic and environmental impacts of increased investments in forest plantations (FAO, 2007a). 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.

Some developing countries would require several years of investment in research and development before they can adopt the technology required for forest energy plantations to become an attractive business. The risks associated with such ventures can be mitigated by using known and well-established species/genetic material (such as *Eucalyptus* spp.). 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.

The wood of species that for various reasons are not used by the timber industry – such as less-known or less-used species – 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 less-known or less-used species for energy in management plans. Energy generation following this approach could increase revenue and improve sustainable forest management (Table 2).

Table 2
Electricity generation potential of wood residues in selected countries

Country	Log consumption (1 000 m³)	Wood residues (1 000 m³)		Electricity generation potential (GWh)[a]	
		Industry	Total[b]	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] Based on use of a steam condensation turbine.
[b] Includes residues from harvesting operations.
Sources: ITTO, 2006; STCP Data Bank.

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.

Countries and private companies that are ready to take the leap into second generation liquid biofuels from cellulosic biomass face an uncertain but potentially lucrative future. The challenge is to find ways of lowering the costs of liquid fuel production from cellulosic biomass by improving existing conversion technologies (Worldwatch, 2006). 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 most developing countries will probably explore other options fully before embarking on this venture.

7. Bioenergy benefits and threats

There is a growing perception that bioenergy offers advantages as an energy option, but there are barriers to be overcome before the full potential of bioenergy can be realized. Some of the potential benefits and possible negative effects resulting from the development of bioenergy systems are summarized in Table 3. The list 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. The potential benefits and costs of investments in bioenergy need to be assessed on a case-by-case or country-by-country basis.

The bioenergy sector is experiencing investments in research and development in both the public and the private sectors (both corporate and smallholder). This will result in increased understanding and help to quantify potential benefits and risks associated with increased production and utilization of biofuels. Developing countries that have started to develop bioenergy industries are the most likely to attract investments and benefits from the resulting technology transfer.

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.

Table 3
Potential benefits and negative effects of bioenergy development

Potential benefits	Potential negative effects
Diversification of agricultural output	Reduced local food availability if energy crop plantations replace subsistence farmland
Increase in food prices and higher income for farmers	Increase in food prices and higher food costs for consumers
Development of infrastructure and employment in rural areas	Demand for land for energy crops may increase deforestation, reduce biodiversity and increase GHG emissions
Substitution of woodfuels for fossil fuels may increase forests and reduce GHG emissions	Increased wood removals above the sustainable production capacity of forests may lead to degradation of forest ecosystems
Diversification of domestic energy supply, especially in rural areas	Displacement of small farmers and concentration of land tenure and incomes
Facilitated access to energy for rural small and medium-sized enterprises	Effects on soil quality and fertility from the intensive cultivation
Increased investments in the recuperation of degraded lands	Possible distorting impacts of government subsidies on other sectors and creation of an uneven playing field in different countries
New revenues generated from the improved use of wood and agricultural residues, and from carbon credits	
A flexible energy source that can produce heat, power and liquid fuels	

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.

Potential negative environmental impacts related to large-scale increases in forest plantations include reduced soil fertility, reduced water conservation, and reduced biodiversity. These impacts can be mitigated through good land use planning and responsible management (FAO, 2006d).

Some studies report that bioenergy investments will help to reduce 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 could also result in increased concentration of landownership, possibly displacing traditional farmers. On the other hand, local planning could result in smallholder investment opportunities for outgrowers.

As a result of the potential risks and conflicts, in some countries there has been resistance to agrofuel projects. In Uganda, for example, there were negative 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 and South Africa (GRAIN, 2007).

In countries where traditional bioenergy is important, energy provision is 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 that 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.

Bioenergy 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. Bionergy developments can reduce indoor air pollution that increases infant mortality and reduces life expectancy in many developing countries. Poor households that depend on traditional biomass could dramatically improve their living conditions if bioenergy development promotes more efficient and sustainable use of traditional biomass, 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. However, the concentration of biomass production and the search for productivity gains for biofuel crops could increase the risk of soil depletion and erosion.

Intensive cultivation also increases and concentrates water consumption, a scarce resource in many 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.

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, regulate water flows and provide shelter and protection to communities and to agricultural lands. 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 conversion to other land uses (Worldwatch, 2006).

The use of agricultural and forest residues could significantly reduce the land requirements for biofuel production, thereby reducing the impact of fuel crop plantations. However, residues are necessary for maintaining soil and ecosystem health, 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).

The intensive use and poor management of natural resources are sometimes 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 threatened when monocultures are grown in large-scale 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).

Deforestation has implications for climate change. The conversion of forest and peat to open new lands for biofuel plantations increases CO_2 emissions. Soya, sugar-cane and oil-palm plantations are examples of developments that have caused deforestation, which is a major cause of GHG emissions in these countries (GRAIN, 2007). 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 is 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 price of oil is high and likely to rise in the future, developing countries need to access the risks associated with investments in bioenergy very carefully. Many 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.

New investments in biofuels often depend on subsidies and new technology developments to be feasible. Developing countries have limited finances and many priorities, so a full assessment of the risks and the identification of ways of maximizing the benefits from investments in bioenergy are fundamental.

8. Policy options and recommendations

Energy consumption will continue to grow. Despite concerns about climate change and energy security, fossil fuels will continue to be the main source of energy over the next few decades.

At the same time, rising fossil fuel prices will encourage countries to become more energy efficient. The gradual conversion from fossil fuels to alternative fuels for the generation of power and for transport is already underway as it is increasingly clear that the long-term trend in prices for fossil fuels is likely to continue upward. Investments in bioenergy research and development are increasing dramatically. Technologies may soon be available to convert cellulose to liquid biofuels on a large scale at economically attractive prices. This could have a tremendous impact on the future management of forests.

Policies and programmes to promote the development of bioenergy alternatives are still in their early stages in most countries. Most such programmes focus on liquid fuels, especially for the transport sector. These policies and programmes tend to be limited in terms of scope, with more attention on regulatory measures than on investments in other relevant areas, such as research and development, market liberalization, information and training. To date there has been relatively little transfer of technology or information about bioenergy from developed to developing countries.

Several developing countries have enormous potential to produce biomass from forests and trees outside forests 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. Effective planning and governance are required to balance the trade-offs between economic, social and environmental impacts and benefits.

In a national strategy, it is 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 can help to reduce greenhouse gases, combat erosion and restore ecosystems; but large-scale monoculture plantations can have negative impacts on soil and water resources.

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. The future energy scenario will not necessarily be an either/or choice between fossil fuels and bioenergy. Most countries will opt for an energy mix where energy from hydro, wind, biomass and traditional sources may be applied in a complementary way.

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.

All countries would benefit from investing in better information about wood energy feedstocks, including biomass recovery from forests and trade of forest biomass. More resources are needed to assess the impacts on the landscape of wood removals for bioenergy production, in particular:

- quantifying the potential of forest biomass to contribute to bioenergy generation, in terms of desired wood energy output (heat, bioelectricity, cellulosic liquid biofuel, etc.);
- evaluating the contributions that natural forests, woody biomass outside forests,

energy plantations, residues and post-consumer material make towards wood energy production;
- determining trade-offs among different land-use decisions;
- aligning data collection efforts to current reporting processes such as the Global Forest Resources Assessment.

All countries need to develop clear national-level policy goals for forests and energy that reflect the principles of sustainable forest management, keeping relevant environmental, social and economic constraints in mind. These goals should differentiate between imported and domestic woodfuels and consider trade-offs between wood- and agrofuels.

The following components could be considered when developing wood energy policy at the national level:
- Based on forest potentials, evaluate policy incentives for the production or consumption of wood energy that reflect possible impacts on other sectors of the economy.
- Consider policy actions that facilitate access to and utilization of forest resources, including transport and handling infrastructures, and economic incentives to ensure the viability of forest biomass recovery for bioenergy production.
- Assess the spatial energy demand and supply situation to identify “hotspots”, e.g. with the help of FAO’s Wood Energy Integrated Supply and Demand Overview Mapping.
- Ensure that policy incentives for wood energy work in synergy with policy in other sectors, such as rural employment, environment protection, land-use management, and the forest products sector.
- Address regulatory issues pertaining to the use of wood energy at all appropriate planning levels (local, national and regional) to ensure that policy incentives for wood energy do not have undesired outcomes.
- Establish sustainability criteria for the wood energy production, conversion and end-use chain. These criteria should take ecological sustainability, environmental conditions, social requirements and economic contributions into account, and should make reference to existing national forest programmes.
- Consider carefully the impacts of bioenergy incentives on other economic sectors in order to avoid “uneven playing fields”.

Continued investment is required in research and development for wood energy applications, including:
- Ensuring flexibility to encourage innovation.
- Supporting research and development throughout the value chain, including developing new value-added products.
- Promoting efficient use of energy and resource inputs and process technologies.

It is important to ensure the participation of all stakeholders when developing and adopting wood energy policies. Forest owners and tenure holders need better information to support informed decisions about management of forest resources, as do the general public and consumers.

Industrialized countries have a moral obligation and economic incentive to develop networks to transfer wood energy technologies to the developing world. The IEA Bioenergy Implementing Agreement is such a network; this approach could be used as a template for developing a participatory network of developing countries interested in technology transfer and bioenergy development:
- Build on existing instruments, such as the FAO wood energy programme, the FAO International Bioenergy Platform and IEA Bioenergy.
- Focus on best practices in wood mobilization and wood energy production and application.
- Focus on education and training, which could play a central role in mobilizing wood resources around the world. This is a joint responsibility of governments, academic institutions, professional bodies, and above all the private sector.

Bibliography

Anon. 1784. *Abhandlung von holzsparenden Stubenöfen*. Walthersche Hofbuchhandlung Dresden.

Bowyer, J.L. & Stockmann, V.E. 2001. Agricultural residues: An exciting bio-based raw material for the global panels industry. *Forest Products Journal*, 51(1): 10–21.

Carrere, R. 2001. Oil palm: the expansion of another destructive monoculture. In *The bitter fruit of oil palm: dispossession and deforestation*, pp. 9–10. London, World Rainforest Movement.

Colchester, M., Jiwan, N., Andiko, Sirait, M., Firdaus, A.Y., Surambo, A. & Pane, H. 2006. *Promised land: palm oil and land acquisition in Indonesia – implications for local communities and indigenous peoples.* Forest Peoples Programme, Sawit Watch, HuMA and the World Agroforestry Centre. Available at: www.forestpeoples.org/documents/prv_sector/oil_palm/promised_land_eng.pdf.

Deloitte Touche Tohmatsu. 2006. *Energy in flux: the 21st century's greatest challenge.* New York.

EIA. 2007. *International energy outlook.* Washington DC.

FAO. 1997. *FAO provisional outlook for global forest products consumption, production and trade to 2010.* Rome.

FAO. 1998. *Global fibre supply model.* Rome.

FAO. 2002. *Economic analysis of wood energy systems.* Rome.

FAO. 2006a. *Global Forest Resources Assessment 2005 – Progress towards sustainable forest management.* FAO Forestry Paper No. 147. Rome.

FAO. 2006b. *State of the World's Forests 2005.* Rome.

FAO. 2006c. Impact of an increased biomass use on agricultural markets, prices and food security: a longer-term perspective, by J. Schmidhuber. Prepared for the International Symposium of Notre Europe, Paris, 27–29 November 2006.

FAO. 2006d. *Responsible management of planted forests: Voluntary guidelines*. FAO Planted Forests and Trees Working Paper FP37E. Rome.

FAO. 2007a. Bioenergy homepage. Rome, Natural Resources Management and Environment Department. Available at: www.fao.org/nr/ben/ben.en.htm

FAO. 2007b. *State of the World's Forests 2007.* Rome.

FAO. 2007c. *FAOSTAT forestry statistics.* Rome.

FAO. 2007d. *FAOSTAT agricultural statistics*. Rome.

Fresco, L.O. 2006. *Biomass for food or fuel: Is there a dilemma?* Amsterdam, the Netherlands, Universiteit van Amsterdam.

GRAIN. 2007. The new scramble for Africa. *Seedling, Agrofuels* special issue. Barcelona, Spain.

IBDF. 1979. *Sumário da viabilidade econômica-financeira da produção de etanol à Partir da Madeira*. Brasilia, Instituto Brasileiro de Desenvolvimento Florestal (IBDF).

IEA. 2004. *World energy outlook*. Paris, International Energy Agency (IEA).

IEA. 2007. Global renewable energy policies and measures Database. Available at: www.iea.org/Textbase/pamsdb/grresult.aspx?mode=gr.

IEA Statistics. 2006a. *Renewables information.* Paris.

IEA Statistics. 2006b. *World energy statistics.* Paris.

ITTO. 2002. *ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests.* ITTO Policy Development Series No. 13. Yokohama, Japan.

ITTO. 2005. *Increase in efficiency in conversion of tropical timber and utilization of residues from sustainable sources.* PD 61/99 rev. 4(I). Yokohama, Japan.

ITTO. 2006. *Annual review and assessment of the world timber situation 2006.* Yokohama, Japan.

Karlsson, Å. & Gustavsson, L. 2003. External costs and taxes in heat supply systems. *Energy Policy,* 31: 1541–1560.

Kellard, N. & Wohar, M.E. 2006. On the prevalence of trends in primary commodity prices. *Journal of Development Economics,* 79(1): 146–167.

Mabee, W.E. & Roy, D.N. 2001. *Fuelwood – an overview. A compendium of plant and animal life-cycle and their impact on the environment,* Vol. 2, pp. 310–317. Calcutta, India, Srebhumi Publishing Company.

Mabee, W.E. & Saddler, J.N. 2007. *Forests and energy in OECD countries.* Forests and Energy Working Paper No. 1. Rome, FAO. Available at: www.fao.org/forestry/energy

Malhi, Y., Meir, P. & Grace, J. 1999. *Forests in flux. Climate change: the threats to world forests.* Edinburgh, UK, World Conservation Monitoring Centre and UNEP.

NAS. 1980. *Firewood crops: shrub and tree species for energy production.* Washington, DC, National Academy of Science (NAS).

NRDC. 2006. Ethanol: energy well spent – a survey of studies published since 1990. New York, Natural Resources Defence Council (NRDC) and *Climate Solutions*, 8.

Obersteiner, M., Alexandrov, G., Benítez, P.C., McCallum, I., Kraxner, F., Riahi, K., Rokityanskiy, D. & Yamagata, Y. 2006. *Global supply of biomass for energy and carbon sequestration from afforestation/reforestation activities.* Mitigation and Adaptation Strategies for Global Change. Dordrecht, the Netherlands, Springer.

Risø. 2003. *Risø energy report.* Stockholm, Denmark, Risø National Laboratory DTU.

Rosegrant, M.W., Ringler, C., Msangi, S., Cline, S.A. & Sulser, T.B. 2005. *International model for policy analysis of agricultural commodities and trade (IMPACT-WATER): Model description.* Washington, DC, IFPRI.

Rosegrant, M.W., Msangi, S., Sulser, T. & Valmonte-Santos, R. 2006. Biofuels and the global food balance. In *Bioenergy and agriculture: promises and challenges.* Hazell, P. & Pachauri, R.K. (eds.). 2020 Focus No. 14, November 2006. Washington, DC, IFPRI.

RSPO. 2007. Roundtable for Sustainable Palm Oil website. Available at: www.rspo.org.

Spitzer, J. & Jungmeier, G. 2006. *Greenhouse gas emissions of bioenergy systems.* European Conference on Bioenergy Research, Helsinki, 19–20 October 2006. Available at: http://ec.europa.eu/research/energy/pdf/gp/gp_events/biorefinery/bs4_03_spitzer_en.pdf.

STCP Data Bank. 1983-. *STCP Engenharia de Projetos Data Bank.* Curitiba, Brasil.

Steierer, F., Fischer-Ankern, A., Francoeur, M., Wall, J. & Prins, K. 2007. *Wood energy in Europe and North America: a new estimate of volumes and flows.* Geneva, JWEE, UNECE/FAO, 6 February 2007.

Tomaselli, I. 1982. *Liquidification of wood.* In *Energy from forest biomass.* New York, Academic Press.

Tomaselli, I. 2007. *Forests and energy in developing countries.* Forests and Energy Working Paper No. 2. Rome, FAO. Available at: www.fao.org/forestry/energy

Trømborg, E., Buongiorno, J. & Solberg, B. 2000. The global timber market: implications of changes in economic growth, timber supply, and technological trends. *For. Pol. Econ.,* 1(1): 53–69.

UNECE. 2007. Timber Committee price database. Available at: www.unece.org/trade/timber/mis/fp-stats.htm.

UNECE/FAO. 2006. *Forest products annual market review 2006*. Available at: www.unece.org/trade/timber/docs/fpama/2006/fpamr2006.pdf.

UNECE/FAO. 2007. *Forest products annual market review 2007*. Available at: www.unece.org/trade/timber/docs/fpama/2007/fpamr2007.pdf.

UN-Energy. 2007. *Sustainable bioenergy: a framework for decision makers.* Available at: www.fao.org/docrep/010/a1094e/a1094e00.htm.

VIEWLS. 2005. *Shift gear to biofuels.* Utrecht, Netherlands, SenterNovem. 60 pp.

Werner. 1797. *Theoretiusch-practische Abhandlung über holzsparende Stubenöfen*. Kochherde und Kochöfen. Bachman n und Sundermann, Hamburg

Worldwatch. 2006. *Biofuels for transportation: global potential and implications for sustainable agriculture and energy in the 21st century*. Washington, DC, Worldwatch Institute.