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Feature Article

A Brief Global Perspective on Biomass for Bioenergy and Biofuels

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Summary

Biomass has a large energy potential. A comparison between the available potential with the current use shows that, on a worldwide level, about two-fifths of the existing biomass energy potential is used. In most areas of the world the current biomass use is clearly below the available potential. Only for Asia does the current use exceed the available potential, i.e. non-sustainable biomass use. Therefore, increased biomass use, e.g. for upgrading is possible in most countries. A possible alternative is to cover the future demand for renewable energy, by increased utilization of forest residues and residues from the wood processing industry, e.g. for production of densified biofuels (Parrika, 2004).

If carried out on a large scale, the increased use of agricultural resources for energy will have the effect of raising the prices of most commodity crops and reducing the need for subsidies – with particular benefit for producers of commodity crops in developing countries. An aggressive program of bioenergy development could lead to reductions in government support to farmers without any loss of income. The long-term success of bio-based facilities and markets is dependent in part on the level of commitment of feedstock from forest landowners and farmers. Forest, crop, and animal residues present considerable potential as a biomass feedstock. They are renewable, sustainable, locally available, and often considered carbon-neutral when compared to fossil fuels (Hoogwijk, 2004; Mathews, 2008).

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Introduction

In recent years, policy makers, legislators, developers, and energy producers have been searching for less expensive, more reliable, and renewable domestic energy sources. Hydro-electric, geothermal, wind, solar, and biomass energy are the most common forms of renewable energy sources that are being used to alleviate our dependency on fossil fuels. Biomass is an attractive choice because it is cost efficient, clean and the only current renewable source of liquid transportation fuel (Perlack *et al.* 2005; U.S.D.O.E. 2010; U.S.D.A. 2009).

The environmental movement of the 1960's spurred the creation of several policies intended to reform emission and pollution practices of the industrial sector in order to provide the nation a cleaner environment. Persistent concerns of society continuing to become more highly mechanized and dependent on fossil fuels created an interest in bio-based projects (Smithhart, 2011).

Biomass essentially began to be examined in the 1970's as a solution to the energy crisis resulting from heavy regulations and predicted shortages within the fossil fuel industry. However, the discovery of fossil fuel reserves followed by a deregulation of the oil industry led to an era of cheap energy. More recently, occurrences such as a global recession along with instability within oil-rich countries, among other factors, inflated energy prices to unprecedented levels (Smithhart, 2011).

Concurrent with increased energy prices is a revitalization of environmental awareness. The 21st century is the beginning of a period with increasing requirements for holistic approaches land stewardship supported by science-based methods to help solve environmental issues. Issues fueling these requirements are soil, water, and air quality to name a few. Added to environmental concerns is increasing demand for energy.

Increases in population, survival rates, and technological advancements are just a few of the social issues augmenting stress to the energy predicament. Many energy producers, developers, legislators, academia, policy makers, and the public are searching for alternative energy sources to alleviate the energy demand and dependency on fossil fuels. These interested parties view renewable energy sources as clean and sustainable solutions. Of the renewable energy sources, biomass feedstock from forestry, agricultural, and livestock industries offer potential to help mitigate environmental issues and stabilize energy needs (Smithhart, 2011).

Recently, several innovations and technology advancements have come from the biomass industry. Advancements within the industry are primarily focused on the areas of harvesting and collection, storage, pretreatment, and conversion of biomass to bio-based products. The preprocessing and pretreatment of biomass also increases the potential gain of biomass to bioenergy efficiency (Meza *et al.* 2008; Jackson *et al.* 2010; Zhu and Pan 2010). Once treated, biomass resources can be converted to energy using a variety of processes to generate electricity, fuel vehicles, residential and commercial heating, as well as provide process heat for industrial facilities. With advancements in biomass technologies in place, energy producers seek sustainable supplies of biomass feedstock to ensure long-term success. Such feedstocks can come from the forestry and agricultural communities.

The continued development of bio-based products and facilities may help to establish several market opportunities for forest landowners, farmers, and poultry producers by providing feedstock in the form of post-harvest residues and dedicated energy crops including trees, crop residues, and animal wastes. If the success of the biomass industry occurs, the diverse markets that emerge will secure the demand for a sustainable supply of biomass feedstock (Smithhart, 2011).

Augmenting fundamental markets are policy initiatives in the form of mandates, incentives, and tax provisions. Government agencies in partnership with industry and academia will likely be focused on achieving goals requiring specific amounts of renewable fuels be produced by future deadlines. Any increases in demand for a sustainable supply of biomass feedstock will challenge forest landowners and farmers to adopt innovative practices. They may be asked or forced into participating in government programs that support bio-based production. Understanding forest and agricultural producers' knowledge and attitudes towards biomass technologies and initiatives can help energy producers and policy makers develop programs tailored for these important groups (Smithhart, 2011).

Since the Kyoto Protocol came into effect in 2005, more attention has been paid to the development of biomass recourse use. This has occurred not only in the industrialized countries, which have an obligation to reduce greenhouse gas emissions under the Kyoto Protocol, but also in developing countries.

Biomass for Fuel

Biomass is considered to be one of the key renewable resources of the future at both small- and large-scale levels. It already supplies 14 % of the world's primary energy consumption. But for three quarters of the world's population living in developing countries, biomass is the most important source of energy. With increases in population and per capita demand, and depletion of fossil-fuel resources, the demand for biomass is expected to increase rapidly in developing countries. On average, biomass produces 38 % of the primary energy in developing countries (90 % in some countries). Biomass is likely to remain an important global source in developing countries well into the next century (Slovak Non-Profit Organizations, 2011).

Managed properly, biomass energy (or bio-energy) can be sustainable, environmentally benign and economically sound. Moreover, biomass energy creates substantial local employment. The advantages are also being recognized in industrialized countries, and several governments have successfully adopted articulate policies for promoting biomass energy. (*Source: Biomass: more than a traditional form of energy*, a publication of the FAO Regional Wood Energy Development Program in Asia in cooperation with the EC-ASEAN COGEN Program and the ASEAN-EC Energy Management Training Research Centre.)

There is an enormous biomass potential that can be tapped by improving the utilization of existing resources and by increasing plant productivity. Bioenergy can be modernized through the application of advanced technology to convert raw biomass into modern, easy-to-use carriers (such as electricity, liquid or gaseous fuels, or processed solid fuels). Therefore, much more useful energy could be extracted from biomass than at present. This could bring very significant social and economic benefits to both rural and urban areas. The present lack of access to convenient sources limits the quality of life of millions of people throughout the world, particularly in rural areas of developing countries. Growing biomass is a rural, labor-intensive activity, and can, therefore, create jobs in rural areas and help stem rural-to-urban migration, whilst, at the same time, providing convenient carriers to help promote other rural industries (Slovak Non-Profit Organizations, 2011). It is now possible with good management, research, and planting of selected species and clones on appropriate soils to obtain 10 to 15 t/ha/yr in temperate areas and 15 to 25 t/ha/yr in tropical countries. Record yields of 40 t/ha/yr (dry weight) have been obtained with eucalyptus in Brazil and Ethiopia. High yields are also feasible with herbaceous (non-woody) crops where the agro-ecological conditions are suitable. For example, in Brazil, the average yield of sugarcane has risen from 47 to 65 t/ha (harvested weight) over the last 15 years while over 100t/ha/yr are common in a number of areas such as Hawaii, South Africa, and Queensland in Australia. It should be possible with various types of biomass production to emulate the three-fold increase in grain yields which have been achieved over the past 45 years although this would require the same high levels of inputs and infrastructure development. However, in trials in Hawaii, yields of 25 t/ha/yr have been achieved without nitrogen fertilizers when eucalyptus is interplanted with nitrogen fixing Albizia trees (De Bell *et al.*, 1989).

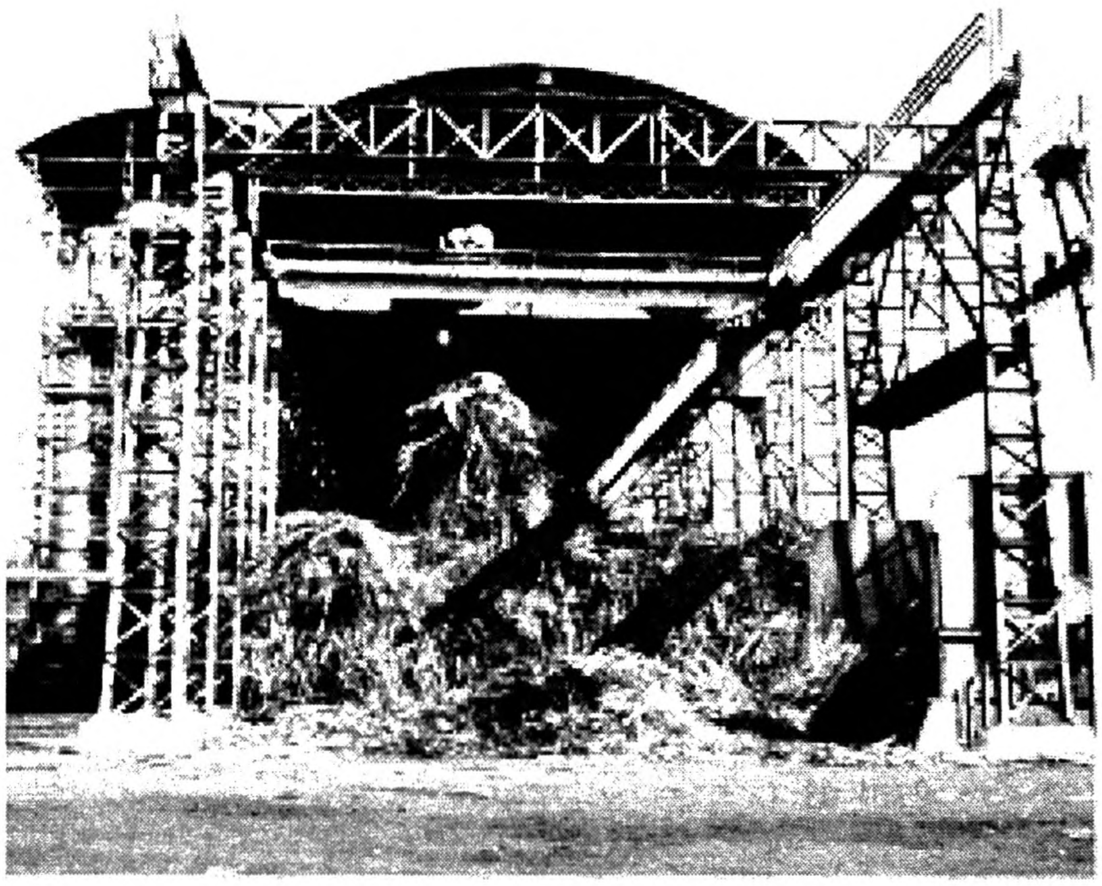

Figure 1: Ethanol plant in Brazil uses the sugar cane to produce sugar, bio-ethanol and electricity with the waste material

World-wide, fermentation capacity for fuel ethanol has increased eightfold since 1977 to about 20 billion liters per year. Latin America, dominated by Brazil, is the world's largest production region of bioethanol. Countries such as Brazil and Argentina already produce large amounts, and there are many other countries such as Bolivia, Costa Rica, Honduras and Paraguay, among others, which are seriously considering the bioethanol option. Alcohol fuels have also been aggressively pursued in a number of African countries currently producing sugar - Kenya, Malawi, South Africa and Zimbabwe. Others with great potential include Mauritius, Swaziland and Zambia. Some countries have modernized sugar industry and have low production costs. Many of these countries are landlocked which means that it is not feasible to sell molasses as a by-product on the world market, while oil imports are also very expensive and subject to disruption. The major objectives of these programs are: diversification of the sugarcane industry, displacement of energy imports and better resource use, and, indirectly, better environmental management. These conditions, combined with relatively low total demand for liquid transport fuels, make ethanol fuel attractive. Global interest in ethanol fuels has increased considerably over the last decade despite the fall in oil prices after 1981.

In developing countries interest in alcohol fuels has been mainly due to low sugar prices in the international market, and also for strategic reasons. In the industrialized countries, a major reason is increasing environmental concern, and also the possibility of solving some wider socio-economic problems, such as agricultural land use and food surpluses. As the value of bioethanol is increasingly being recognized, more and more policies to support development and implementation of ethanol as a fuel are being introduced (Slovak Non-Profit Organizations, 2011.)

Expanding use of biofuel will provide precious opportunities for rural people to improve their welfare, since most of the energy crops are mainly produced by small-scale farmers who are vulnerable to price fluctuations. An increasing demand for energy crops has the potential to contribute to increased and stabilized prices of their produce. Moreover, the installation of biofuel processing plants will increase job opportunities, mainly for rural poor people. This is because the biofuel production should be done near the feedstock production areas, due to the high transportation costs of bulky raw materials. On the other hand, if the government fails to manage the biomass resource development appropriately, some negative impacts will occur such as natural forest destruction, conflict with food production, and contamination of natural water systems by excess inputs into farmlands (UNESCAP-CAPSA, 2008.)

The production of biofuel feedstock provides an opportunity for many countries to capture part of the global fuel market share by investing in production and upstream refining, both to save foreign currency and to earn from exports. Biofuels also provide a unique and vast market to link remote, generally uneconomic and degraded areas, where many of world's poorest people live, to global markets (UNESCAP-CAPSA, 2008). These trends not only open a vast area of opportunity for the poor, many of whom live in areas well-suited to biofuel production, but they may also cause some basic shifts in agricultural production patterns as land is diverted from food crop production to production of biofuels to meet the increasing energy needs of the world (UNESCAP-CAPSA, 2008)

Biomass Conversion to Energy

Biomass resources can be converted to energy using a variety of processes in order to meet the need of generating electricity, fueling vehicles, residential and commercial heating, and providing process heat for industrial facilities. Although conversion technologies of biomass are extensive and numerous, most of the methods mentioned are geared toward uses in advanced bio-facilities and are flexible in that they can also be used in other agricultural applications. Biomass conversion technologies can be broadly divided into two categories: thermochemical processes and biochemical processes.

Direct combustion of biomass is one of the most common and oldest processes used today. The process of direct combustion combines air with fuel to produce heat, water, carbon dioxide, ash, and trace compounds. For residential purposes, energy can be created using direct combustion in stoves and small scale furnaces. Direct firing at an industrial level uses furnaces or boilers to produce process heat, electricity, or both in a combined heat and power (CHP) system.

Some of the most common biomass combustion boiler designs are pile burners, stoker-fired furnaces (fixed bed furnaces), suspension-fired furnaces (pulverized fuel systems), and fluidized bed furnaces (Saidur *et al.*, 2011). Pile burners and stoker-fired furnaces require less capital investment than other combustion technologies; however, they have less efficiency gains (Jackson *et al.*, 2010). Suspension-fired furnaces achieve high efficiency utilizing technology common to the coal industry for coal-fired furnaces. Fluidized bed furnaces are new to boiler technologies that have an ability to handle a wider variety of fuels and moisture content as well as having the highest thermal conversion efficiencies due to more complete combustion when compared to other boiler technologies (Saidur *et al.*, 2011). Potentially, CHP systems have a wide range of small and large scale applications combined with higher efficiencies rendering lower emissions than systems producing separate heat and power.

In gasification, biomass is heated in a high temperature environment with steam, air, and oxygen until volatile gases are released (Combs, 2008). The gaseous mixture of hydrogen, carbon monoxide, carbon dioxide, and other compounds can be mixed with oxygen and burned to produce steam to operate a turbine and generate electricity. Alternatively, the gases can be cooled, filtered, purified, and stored as a synthesis gas, or syngas, to be used as fuel for internal combustion engines, gas turbines, etc. A major cost associated with gasification is tar removal and/or clean up (Jackson *et al.*, 2010). However, another gasification process using supercritical water (high temperature steam conditions) offers low levels of char formation and the ability to use high moisture feedstock (Jackson *et al.*, 2010).

Pyrolysis is the gasification of biomass in the absence of oxygen and converts wood biomass to a mixture of solid, liquid, and gas (Saidur *et al.*, 2011). The advantages of pyrolysis include a flexible process of converting solid biomass into an easily stored and transportable fuel, which can be successfully used for the production of heat, power, and chemicals. Slow pyrolysis (e.g. charcoal production) converts feedstock using relatively low temperature levels and long reaction times, whereas fast pyrolysis produces small molecules by converting feedstock at high temperature levels (Jackson *et al.*, 2010). The process transforms the biomass into pyrolysis oil (or bio-oil) or syngas without creating ash or energy directly.

Torrefaction is a form of mild pyrolysis that pre-treats wood biomass at relatively low temperatures of 200-300°C in the absence of oxygen (Bergman and Kiel, 2005). Gasification of wood biomass is comparatively low at less than 700°C due to high oxygen to carbon (O/C) ration of the fuel and moisture content leading to thermodynamic losses (Prins *et al.*, 2006). As a pretreatment to gasification, torrefaction produces a solid material with high energy efficiencies, lower MC, lower O/C ratio, and is hydrophobic in nature (Jackson *et al.*, 2010). Also, it improves the properties of biomass enabling more efficient co-firing at bio-facilities (Bergman and Kiel, 2005).

Biochemical conversion is a chemical decomposition of biomass' cell wall using cellulase enzymes or acids in order to extract sugars for conversion to ethanol (U.S.D.O.E., 2008). Specifically, lignocellulosic hydrolysis is a process of utilizing cellulase enzymes to produce sugar. After the hydrolysis stage, fermenting organisms (e.g. yeast) are added to the mixture inside the fermentor to convert sugars to alcohol and carbon dioxide (Jackson *et al.*, 2010; U.S.D.O.E., 2008).

Biomass Conversion Challenges

In the U.S., shifting power generating capacity to biomass will not be easy. Biomass as a fuel source for large-scale power generation is in its infancy. Suppliers and supply chains have not yet been developed on the scale necessary to supply volume of biomass necessary to meet U.S. power needs. Unlike the coal supply chain that has been in place for many years, it is not clear at present how the biomass supply chain will or should develop. This is made more complex as numerous utilities are considering entering the biomass market before it is well understood how the competition for fuels sources could evolve. Key questions for a utility considering a conversion to biomass is likely to include the following: Type of biomass: Wood vs. agricultural products, raw vs. pelletized, purpose grown vs. byproduct/residual; torrefaction; specifications (Btu content, moisture content, size, emissions); Sourcing: Biomass origins, suppliers, producer facility sizes, pellet plant locations (if applicable); Transportation: Modal options, equipment requirements, unloading infrastructure, delivery quantities; Storage/Handling: Type of fuel storage (indoor for certain types of biomass pellets), conveying infrastructure, dust control systems, fire suppression systems and; Boiler: Type of boiler to use or boiler conversion options.

Each involves a variety of options and trade-offs that must be considered when developing a biomass supply chain. In addition, each may include significant capital requirements. For example, boiler modifications, transportation equipment, unloading infrastructure, storage facilities and other potential requirements could add up to a significant expense depending on the needs of a specific utility or generating facility. (Clair, 2010)

Primary Biomass Feed-stocks: Wood and Agricultural Materials

Where great civilizations have evolved, wood has been universally present and utilized. Primitive uses for wood included tools, weapons, shelter, and an energy source. As societies have advanced, so has their use of wood. Besides cooking, heating, weaponry, and furniture making, Americans began to develop advanced applications for wood in industrial settings. Developments in industrial construction led to the building of water mills, wind mills, machinery frames, and mechanized machinery such as axles and gears (Stuart and Grace, 2009). As an energy source wood was, and still is, being used in direct combustion devices such as fireplaces, woodstoves, and industrial boiler systems (Hewett *et al.*, 1981). Wood may be the best-known example of biomass. When burned, the wood releases the energy the tree captured from the sun's rays. But wood is just one example of biomass. Various biomass resources such as agricultural residues (e.g. bagasse from sugarcane, corn fiber, rice straw and hulls, and nutshells), wood waste (e.g. sawdust, timber slash, and mill scrap), the paper trash and urban yard clippings in municipal waste, energy crops (fast growing trees like poplars, willows, and grasses like switchgrass or elephant grass), and the methane captured from landfills, municipal waste water treatment, and manure from cattle or poultry, can also be used (Slovak Non-Profit Organizations, 2011.)

Wood energy is drawing increasing attention as an environmentally friendly source of energy. Wood is still people's main source of fuel for cooking, processing and preserving food, and will continue to be for many years to come. Worldwide, 2 billion people depend on wood for cooking, a basic step in ensuring proper nutrition. In many developing countries, fuelwood supplies as much as 97 percent of total energy consumption. Wood-based energy systems are the most readily available in many areas and, when properly managed, they are not only versatile and sustainable but also effective in generating income and jobs (WTO, 1999)

Although most research on biomass as an energy source was primarily on wood biomass agriculture continues to grow in interest as a cellulosic feedstock (Bain, 1993). With agricultural productivity on the rise, cellulosic biomass from agricultural feedstock has great potential to displace future gasoline production (Fuglie, 2010; Kim and Dale, 2004). Advancements in plant breeding have resulted in increased yields and quality (Dimitri *et al.*, 2005). Thus, cellulosic biomass sources offer immense potential as feedstock for future biofuel production (Westscott, 2007; Powlson *et al.*, 2005).

Figure 2: Logging slash and other wood residues left after timber harvests are ideal sources of wood biomass for energy production

Biomass and Energy Development in Developing Countries

Though developing countries have no obligation under the current Kyoto protocol, if an industrialized country assists a developing country in reducing emissions, it can be counted as an achievement by the industrialized country. The mechanisms are expected to promote investment in renewable energy development in developing countries, especially in the disadvantaged areas that are production centers of secondary crops used as raw materials for biomass energy (UNESCAP-CAPSA, 2008).

The UN FAO 2007 forest report states: "Deforestation and forest degradation will continue in most developing regions; a reversal of the situation would depend on structural shifts in economies to reduce direct and indirect dependence on land. In most developing tropical countries, agricultural land used for both subsistence and commercial cultivation continues to expand. Consequently, loss of forests will continue." "While heating and cooking will remain the principal uses for fuelwood and charcoal in developing countries, the use of solid biofuels for the production of electricity is expected to triple by 2030" (UN FAO, 2007).

"Wood energy could become a motor for the development and expansion of forestry activities. Progressive policies are required to ensure that these changes help alleviate poverty in developing countries. ... new energy and environmental policies are making wood fuel an essential ingredient of energy policy in both developed and developing countries. In developed countries, it is likely that the use of wood for energy will continue to increase. For many developing countries, wood will remain the most important source of energy. The rising price of oil and increasing concern for climate change will result in increased use of wood as fuel in both developed and developing countries" (UN FAO, 2007).

These are very telling statements: "new energy and environmental policies are making wood fuel an essential ingredient of energy policy in both developed and developing countries"... and "increasing concern for climate change will result in increased use of wood as fuel in both developed and developing countries". The environmental policies that are referred to are the anti-fossil-fuel policies, wherein the burning of wood is deemed preferable because it is "renewable biomass". The fact that burning wood releases more greenhouse gases per unit of energy released than burning oil or natural gas does, is simply overlooked. The assumption is that the wood will be re-grown and absorb as much CO_2 from the atmosphere as released in the burning.

Bioenergy production as heat, electricity, and liquid fuels represents about 14% of the World's primary energy supply. About 25% of the usage is in industrialized countries and the other 75% is used in developing countries. The total sustainable worldwide biomass energy potential is about 100 EJ/a (the share of woody biomass is 41.6 EJ/a), which is about 30% of total global energy consumption today. About 40 EJ/a of available biomass is used for energy. Nearly 60% of this biomass is used only in Asia. A comparison between the available potential with current use shows that on a worldwide level about two-fifths of the existing biomass potential is used, and in most areas of the world the current biomass use is clearly below the available potential. Only in Asia does the current use exceed the available potential. Therefore, an increased biomass use is possible, e.g. for production of densified biofuels, in most countries (Parikka, 2004).

The total above-ground wood volume (m^3) and woody biomass (tons) in forest has been estimated in 166 countries, representing 99% of the world's forest area (Table 1). The world's total aboveground biomass in forests is 420 (109) tons of which more than 40% is located in South America and about 27% is in Brazil alone (FAO, 2001).

Biomass currently represents approximately 14% of world's final energy consumption (IEA, 1998). About 25% of the usage is in industrialized countries, where a significant level of investment in environmental protection has been made to meet emissions standards, especially air emissions (Overend, in Sayigh, 2002). The other 75% of primary energy use of biomass is in heat production for developing country household energy needs and in process heat production for biomass-based industries through the use of their generated (Overend in Sayigh, 2002). Estimates of global potential for biomass that can be converted into fuels vary widely. One recent study concluded that by 2050, biomass theoretically could supply 65% of the world's current energy consumption, with sub-Saharan Africa, the Caribbean, and Latin America accounting for roughly half of this global potential (Smeets *et al.*, 2004). In tropical countries, high crop yields and lower costs for land and labor provide an economic advantage that is hard for countries in temperate regions to match (Worldwatch Institute, 2006).

Table 1. Forest resources, above-ground biomass volume and biomass (m^3 and tons)

	Forest area (ha) (10^9)	Volume (m^3/ha)	Volume (ha) (10^9)	Woody biomass (tonne/ha)	Woody biomass (tonne/ha)
Africa	649	72	46	109	70
Asia	547	63	34	82	44
Europe	1039	112	116	59	61
North and Central America	549	123	67	95	52
Oceania	197	55	10	64	12
South America	885	125	110	203	179
World	3869	100	386	109	421

FAO, FAOSTAT-database 2002, http://ww.fao.org, 2002
FAO, State of the World's Forests-2001, www.fao.org, 2001

Plans for increased biofuels production are also advancing in Latin America (including Colombia and Peru), Asia (India, Thailand, Malaysia),Australia, Africa (especially South Africa but possibly also Zimbabwe, Madagascar, Malawi, and Mozambique), and Eastern Europe (Romania, Ukraine, and Russia) (Smeets *et al.*, 2005). For example:

- The Indian government has identified nearly 100 million acres of land where jatropha can be grown as a biofuel and hopes to replace 20% of diesel consumption in five years (Casey, 2006).

- Malaysia, the world's top producer of palm oil, has approved licenses for 52 biodiesel plants with a combined capacity of 1.5 billion gallons a year (Reuters, 2006). (However, the destruction of tropical forests for palm cultivation is a major environmental concern (Friends of the Earth International, 2004).

- The Australian government has set a target of producing nearly 100 million gallons of ethanol annually by 2010 (Nash, 2005).

Biomass provides a surprisingly large amount of the world's energy – 10% of total global primary energy consumption – but most of that is wood and charcoal gathered and used in the most primitive ways. Sustainable biofuel development can help bring modern energy services to more people, particularly in rural areas. It can also foster greater investment in agriculture, which employs 75% of the world's poor. It can create new job opportunities in rural areas and provide a major new source of income for farmers (Roche and Perez, 2006). By producing transportation fuel, farmers will be entering a market with higher prices and rising demand. Growing energy crops is more likely to attract the kind of foreign investment that can modernize their agricultural practices – and increase their food production as well.

The Food and Agriculture Organization of the United Nations notes these benefits as well: "Energy plantations and crops (in particular perennial crops) can help to prevent soil erosion by providing a cover which reduces rainfall impact and sediment transport. Annual energy crops can also allow diversification and expansion of crop rotations. Deforested, degraded and marginal land could be rehabilitated as bioenergy plantations which could combat desertification and increase food production." (FAO, 2005).

Bio-based Energy in Tropical Countries

Tropical and subtropical forests comprise 56% of the world's forests, while temperate and boreal forests account for 44% (FAO, 2001). Tropical countries enjoy favorable conditions for growing biomass. However, constraints to optimal use as an energy source are still to be resolved. The main issues are legal and institutional barriers, as well as a lack of information and technology transfer. Furthermore, common misconceptions about biomass energy have to be redressed. It should be emphasized that the larger part of wood fuels comes from non-forest land; wood fuel use is not the root cause of deforestation; biomass energy is more than a traditional commodity; and biomass energy will not phase itself out in the foreseeable future.

The tropical Asian countries have a large potential for biomass production. It is expected that various projects of large-scale energy crop production (e.g. cassava, oil palm, sugar cane, etc.) will be implemented in the near future under the initiatives of both industrialized countries, through CDM schemes, and tropical Asian countries themselves. For Example, the Government of Indonesia will set a biofuel (bioethanol and biodiesel) target of about 10 per cent of the country's energy portfolio by 2010. The government also expects the sector to create around 3 million jobs and cut foreign exchange expenditure for importing fuel by US$ 10 billion by 2010. To this end, the government will allocate 6.5 million ha of idle land for investors interested in planting energy crops. Of the total land allocation, some 3 million ha will be allocated for oil palm, 1.5 million ha for jatropha, 0.5 million for sugar cane and 1.5 million ha for cassava (The Jakarta Post, 25 July 2006).

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