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Bioenergy resources: an introduction

Bioenergy is energy of biological and renewable origin, normally in the form of purpose-grown energy crops or by-products from agriculture, forestry or fisheries. Examples of bioenergy resources are fuel wood, charcoal, sugar bagasse, sweet sorghum stocks, livestock manure, biogas, microbial biomass and algae.

Biomass provides approximately 11–14% of the world's energy (IEA, UNDP, WEC), but there are significant differences between industrialised and developing countries.

In many developing countries biomass is the most important energy source. As a global average, biomass provides approximately 35% of developing countries' energy (WEC, UNDP), but there are large regional differences. Many sub-Saharan African countries, for instance, depend on biomass for up to 90% of their energy, indicating that they have little in the way of industry or other modern activities.

The main sources of biomass in developing countries are traditional wood fuels, either collected and used in a non-commercial way or bought in local markets as firewood or charcoal.

In industrialised countries, biofuels have for a long time been considered as old-fashioned because of their bulky nature and low energy content compared to fossil fuels. In the last decade, however, interest in bioenergy has increased. Reasons for this include:

- Growing concern about climate change – biofuels can be carbon-neutral if they are produced in a sustainable way;
- Technological advances in biomass conversion, combined with significant changes in energy markets;
- Biofuels have the unique characteristic of being the only sources of renewable energy that are available in gaseous, liquid and solid states;
- Increasing focus on security of energy supply; and
- Increasing interest in renewable energy generally.

So while many developing countries will aim at reducing dependence on traditional bioenergy fuels as part of policies to improve access to modern energy services, the global trend is expected to focus on how to increase the share of modern bioenergy in the global energy mix.

Examples of current bioenergy use in industrialised countries are the USA (4%), Sweden (17%) and Finland (20%) (WEC). Data on bioenergy resources and utilisation is generally uncertain because of the very diverse and dispersed nature of the resources. In most statistics, bioenergy resources are usually classified as either animal manure or plant biomass, the latter including municipal and other solid waste.

Bioenergy could in principle provide all the world's energy requirements, but its real technical and economic potential is much lower. The WEC Survey of Energy Resources (WEC 2001) estimates that bioenergy could theoretically provide 2900 EJ/y, but that technical and economic factors limit its current practical potential to just 270 EJ/y. Current use of bioenergy is estimated at around 55 EJ/y.

Figure 2 shows the potential and current use of bioenergy by region, based on data from Kaltschmitt. Even with the current resource base, it is clear that the practi-

Table 1. Types of plant biomass. Source: UNDP, 2000.

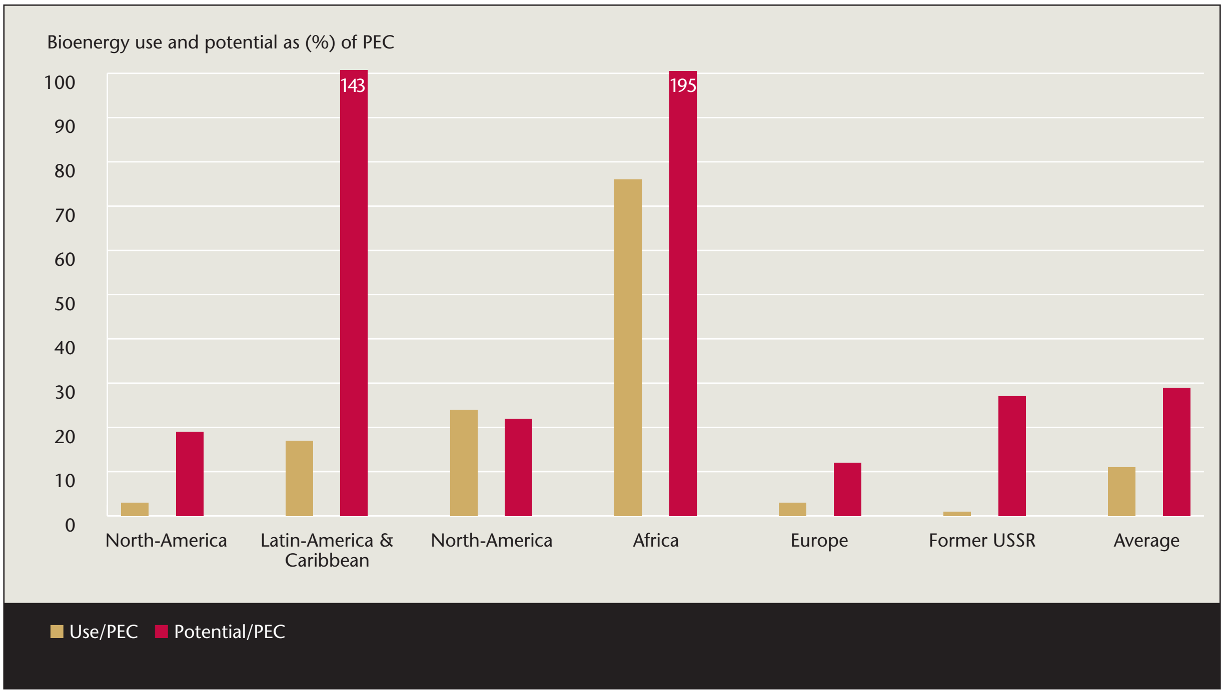
Woody biomass	Non-woody biomass	Processed waste	Processed fuels
Trees Shrubs and scrub Bushes such as coffee and tea Sweepings from forest floor Bamboo Palms	Energy crops such as sugar cane Cereal straw Cotton, cassava, tobacco stems and roots (partly woody) Grass Bananas and plantains Soft stems, such as those of pulses and potatoes Swamp and water plants	Cereal husks and cobs Bagasse Wastes from pineapple and other fruits Plant oil cake Sawmill wastes Industrial wood bark and logging wastes Black liquor from pulp mills Municipal waste	Charcoal (wood and residues) Briquetted or densified biomass Methanol and ethanol (wood alcohol) Plant oils such as palm, rapeseed (canola) and sunflower Producer gas Biogas

cal potential of bioenergy is much greater than its current exploitation. Obstacles to greater use of bioenergy include poor matching between demand and resources, and high costs compared to other energy sources.
Projections by the WEC, WEA and IPCC estimate that by 2050 bioenergy could supply a maximum of 250–450 EJ/y, representing around a quarter of global final energy demand. This is consistent with Figure 2, which puts the technological potential of bioenergy at 25–30% of global energy demand.

Land availability

Growing biomass for energy production on a significant scale consumes both land and labour. Land use in particular is a key issue in the production of bioenergy resources, because using land for energy crops means that less land is available to grow food.
It is imperative to ensure that sufficient cropland is available to produce food for the world's expanding population, taking into consideration that biomass energy can help enhance development and food production.
Studies by the FAO and others point to significant reserves of potential cropland, but these resources are not distributed where they will be needed most if present predictions about population growth and competition for land use hold true.
In the industrialised countries, much of the land being removed from agricultural production could profitably and responsibly be used for energy production, because of the associated benefits of such land use. The EC's "set-aside" policy, which encourages farmers to keep part of their land fallow, and similar schemes in other countries such as the US are making significant areas of land available. Growing biomass crops on this land could help to re-invigorate rural economies, as well as providing bioenergy and its associated environmental benefits.
In the non-industrialised world, land availability varies between regions and between countries. Some Asian countries appear to have no, or almost no, spare land that could be used for bioenergy. Even in these countries, however, strategies such as agroforestry, efficient energy conversion technologies and the use of agricultural wastes could create significant amounts of bioenergy. Latin America, much of Africa, and several forest-rich countries in Asia have large areas which could be used for bioenergy, given the right long-term policies.
In many developing countries, food and fuel production can be integrated in complementary land use systems. In fact, at the small to medium scale (100 kW–1 MW), agricultural residues and non-arable land can supply villagers' energy needs for domestic water, irrigation, lighting and cooking. Irrigation can greatly increase crop yields, so the implication is that at this scale the use of indigenous biofuels does not need to consume extra land resources. The production of excess biomass can be converted to higher value energy products e.g. charcoal, electricity or synthetic biofuels, which can be sold on the open market. Firewood and charcoal are already significant income sources in rural areas.
At the larger MW scale, land use conflicts could occur where dedicated energy plantations are to supply a central conversion facility i.e. where a bioenergy market is

Figure 2. Technical potential and use of biomass as a percentage of primary energy consumption (PEC) from fossil fuels + hydropower (Based on data from Kaltschmitt 2001).



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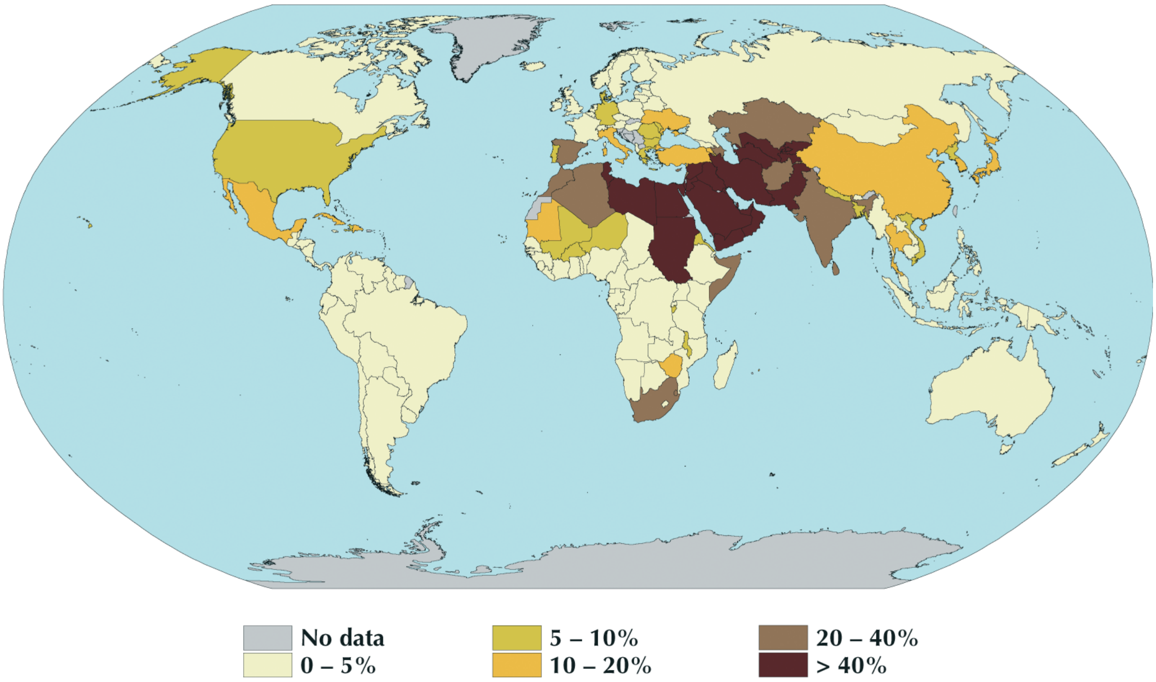

Figure 3. Agricultural water withdrawals: FAO (2003): Agriculture, food and water. A contribution to the World Water Development report. FAO, Rome

stimulated. Since biomass is a low energy density fuel, high transport costs require that the conversion facility secure supplies from as close to the plant as possible. Thus, measures to protect the small farmer near to such a plant may be necessary. However, concerns must also be measured against the benefits accrued by such a plant i.e. increased rural employment (at all skill levels), a secure market for agricultural products and the provision of cheap indigenous supplies of energy.

Bioenergy production can be a way to rehabilitate marginal and degraded land and bring it back into profitable use. This will only happen, however, if it is supported by policy. Without such policy, there is a danger that bioenergy producers will seek good land, where yields are higher, and so compete directly with food production.

Water restrictions

One in five developing countries will face water shortages by 2030. The biggest consumer of water is agriculture, which accounts for around 70% of all freshwater withdrawals worldwide. With a growing world population, agriculture will face more competition from industrial and domestic water users. As a result, agriculture will have to use water more efficiently.

Figure 3 shows agricultural water withdrawals by region as a percentage of water available, and so indicates the level of “stress” caused by current agricultural practices. If bioenergy resources are to meet their full potential, they will have to match the water consumption of other crops in the same region.

Wood, the traditional fuel

Lack of access to convenient and efficient energy is a major barrier to achieving meaningful and long-lasting solutions to poverty. Access to energy is essential in alleviating poverty and achieving sustainable development goals, because it supports strategies for improving employment, education, water supply, public health, local self-sufficiency and a host of other development benefits.

Fuel wood and charcoal are the dominant sources of energy for about half the world’s population. In many countries they also constitute the major forest products. Two to three billion people rely on wood for their primary energy needs and to provide a wide range of other essential goods and services.

For many of these people, wood is far from being a clean and efficient energy source, it is simply their only affordable option. Compared to conventional fossil fuels, wood-fuel and charcoal have low calorific values and are difficult to handle, expensive to transport over long distances and considered dirty in most residential contexts. In many cases, the harvesting of wood-fuels also causes deforestation and loss of vegetation cover.

These negative perceptions are not easily changed, and they restrict the options open to policymakers. This is despite the fact that several countries, both industrialised and developing, have shown that many of the drawbacks can be overcome by using the right technology.

In fact, it is often not understood that appropriate wood-based energy systems can contribute significantly to sustainable development, particularly in the poorer areas of developing countries. Wood fuels have some advantages over other energy sources:

- They contribute to poverty reduction in developing countries;
- They meet energy needs at all times, without expensive conversion devices;
- They can deliver energy in all the forms that people need (liquid and gaseous fuels, heat and electricity);
- They are CO_2-neutral, and can even act as carbon sinks; and
- They help to restore unproductive and degraded lands, increasing biodiversity, soil fertility and water retention.

Wood fuels usually form part of larger multi purpose systems within forests or agricultural areas. These systems also provide non-wood forest products, reservoirs of biodiversity, traditional medicines and shelter from the wind and sun, all at little or no cost to the world's poorest people. Moreover, most of the added value from village-scale bioenergy systems is retained locally and helps to reduce poverty.

But although wood fuels are widely available and affordable in rural areas of most developing countries, many resources still remain untapped. For wood energy to fulfil its potential as an instrument for sustainable development, a series of technological, institutional, economic and social challenges need to be addressed.

Fuel of the Future

With the traditional association of bioenergy as old fashioned and for the poor, the recent interest in biomass resources has invented a new term "modern bioenergy" which covers a number of technological areas from combustion at domestic, industrial or power plant scale, gasification, hydrolysis, pyrolysis, extraction, digestion etc.

Most of these technologies have been available for decades but recent advances in performance have made them economically interesting in view of the resource potential and the possibility of improving environmental performance often along with local employment opportunities. Details concerning individual bioenergy conversion technologies are presented in chapter 5.

Driving forces and practical limitations

Two trends emerge from the discussions above:

a. Developing countries will in general aim to reduce their dependence on traditional bioenergy as part of their development strategies. The relative share of bioenergy in the energy balance will therefore go down, though the number of people depending on traditional bioenergy will probably remain constant, with corresponding consequences for health and resources.

b. Industrialised countries, plus a number of developing countries, will aim to increase their use of modern bioenergy technologies.

Practical limits to bioenergy expansion

Practical limits to bioenergy expansion are set by factors including:

- Resource potential and distribution (as discussed in the Introduction);
- Technological development state of the biomass conversion technologies;
- Costs of technologies and resources;
- Lack of social and organisational structures for fuel supply;
- Public acceptability; and
- Land-use and environmental aspects.

Most of these barriers to the increased use of bioenergy can be overcome through dedicated interventions by both public- and private-sector entities, focusing on:

- Developing and deploying cost-effective conversion technologies;
- Developing and implementing improved dedicated bioenergy crop production systems;
- Establishing bioenergy markets and organisational structures to transport and deliver bioenergy resources and products; and
- Valuing the environmental benefits to society, such as on the carbon balance.

Driving forces to support these activities will be:

- Security of energy supply, which can be increased by using domestic resources;
- Employment and land-use aspects (both for and against the increased use of biofuels);
- Global concerns about climate change; and
- Local concerns about health issues related to burning biofuels indoors.

All of these driving forces in support of biofuels require targeted policy interventions to ensure that the social benefits of increased bioenergy use are properly reflected in the energy markets. In some cases "smart" subsidy schemes may even be needed to ensure that new bioenergy resources and technologies get a level playing field in established energy markets.

A concrete example of a large-scale bioenergy programme is Brazil's PRO-ALCOOL, in which ethanol from sugar cane bagasse is used as a transport fuel. In 1999 Brazil produced and used about 13 billion litres of ethanol in this way (UNDP, 2000).

The PRO-ALCOOL programme was launched in 1975 as a response to the oil crises. In spite of mixed economic results it has been a technical success, and has provided both social and environmental benefits.

The cost of producing the ethanol is equivalent to an oil price of around USD 30 per barrel. When oil prices are

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below this level, the country must pay to produce fuel that could be imported more cheaply as oil.

The beneficial effects of lowering imports by USD 20–30 billion, creating (directly and indirectly) almost a million jobs, cutting air pollution in urban areas and reducing energy-related carbon emissions by 15–20% can be offset against this.

Specific national circumstances mean that it may not be possible to replicate the Brazilian example directly. The PRO-ALCOOL programme does show, however, that good policymaking in response to the driving forces mentioned above can create effective bioenergy solutions. The programme has contributed significantly to overcoming the technological barriers to the wider use of ethanol, not just in Brazil but also worldwide.