Emerging international bio-energy markets and opportunities for socio-economic development

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Rapidly developing international bio-energy trade may evolve over time into a "commodity market" which can secure supply and demand in a sustainable way; sustainability being a key factor for long-term security. It is clear that on a global scale and over the longer term, large potential biomass production capacity can be found in developing countries and regions such as Latin America, Sub-Saharan Africa and Eastern Europe. If indeed the global bio-energy market is to develop to a size of 400 EJ over this century (which is quite possible given the findings of recent global potential assessments) the value of that market at US$ 4/GJ (considering pre-treated biomass such as pellets) amounts some US$ 1.6 trillion per year.

This creates important future opportunities for such regions, given the expected increased role of bio-energy within the world's energy supply. Consequently, this poses the fundamental question of how these potential major producers and exporters of bio-energy can benefit from the growing global demand for bio-energy in a sustainable way, i.e., that bio-energy exports can contribute to rural development, benefit local communities and be an integral part of overall development schemes, including the existing agricultural and forestry sectors.

In this paper the links between international bio-energy trade and socio-economic development and how sustainable bio-energy production could be realized are explored. Drivers, barriers and future potentials for international bio-energy markets are discussed and socio-economic implications for possible exporting countries are identified. By doing so, several key opportunities and issues for the developing international bio-energy markets and their possible socio-economic impacts on developing and rural regions are raised that should be taken into account by policy-makers, market parties, international stakeholders and other key stakeholders.

Summarizing, although international bio-energy trade and markets are developing very rapidly and the future looks bright given market demand and potential supplies, many barriers also exist that can disturb or at least slow down a sound development of such markets. Also, there are important concerns about competition for land that may result in conflict with food production, water resources and biodiversity protection. Although biomass production may well provide a crucial strategy to enhance sustainable land-use management, negative developments should be avoided, e.g., by clear standards and best-practice guidelines for (the design of) biomass production systems and their integration in agricultural areas.

1. Introduction

Over recent decades, the modern use of biomass has increased rapidly in many parts of the world. In the light of the Kyoto Protocol's greenhouse gas (GHG) reduction targets, many countries have ambitious targets for further biomass utilization. Also the, recent increase of the oil price has strongly fuelled the interest in bio-energy. For example, at an oil price of over US$ 60 per barrel (1 barrel of oil = 136.4 kg), it is a very attractive option to drive on bio-ethanol derived from sugar cane instead of fossil fuel-based transportation fuels. At present, biofuels are seen as a key diversification strategy to reduce the dependence on mineral oil, and thus to improve energy supply security.

Although, especially in developed countries, domestic biomass potentials are often used to a high degree, in some countries untapped potentials still remain. In the longer term, the pressure on available biomass resources will increase. Also, biomass produced in developed countries can generally be associated with higher production costs.

Ambitions and expectations for biomass use for energy are high in many countries, for the EU and also on a global basis, given a variety of policy objectives and long-term energy scenarios. A reliable supply and demand of bio-energy is vital to develop stable market activities. Given the expectations for a high bio-energy demand on a global scale and in many nations, the pressure on available biomass resources will increase. Without the development of biomass resources (e.g., through energy crops and better use of agro-forestry residues) and a well-functioning biomass market to assure a reliable and lasting supply, those ambitions may not be met. The development of truly international markets for bio-energy may become an essential driver to develop bio-energy potentials, which are currently underutilised in many regions of the world. This is true for both residues and for dedicated biomass production (through energy crops or multifunctional systems such as agro-forestry).

The underutilisation of biomass potentials applies to both available residues and possibilities for dedicated biomass energy plantations or multifunctional systems such as agro-forestry. On the other hand, many developing countries have a large technical potential for agricultural and forest residues and dedicated biomass production, e.g., ethanol from sugar cane, wood or other crops. Given the lower costs for land and labour in many developing countries, biomass production costs are much lower, and thus offer an opportunity to export bio-energy.

The possibilities of exporting biomass-derived commodities to the world's energy markets can provide a stable and reliable demand for rural communities in many (developing) countries, thus creating an important incentive and market access that is much needed in many areas of the world. For many rural communities in developing countries such a situation would offer good opportunities for socio-economic development.

Sustainable biomass production may also contribute to the sustainable management of natural resources. Importing countries on the other hand may be able to cost-effectively meet their GHG emission reduction targets and diversify their fuel-mix.

The future vision for global bio-energy trade is that it develops over time into a real "commodity market" which will secure supply and demand in a sustainable way; sustainability being a key factor for long-term security. It is clear that on a global scale and over the longer term, large potential biomass production capacity can be found in developing countries and regions such as Latin America, Sub-Saharan Africa and Eastern Europe. This creates important future opportunities for such regions, given the expected increased role of bio-energy within the world's energy supply. Such developments could give access to an open world energy market. Consequently, this poses the fundamental question of how these potential major producers and exporters of bio-energy can benefit from the growing global demand for bio-energy in a sustainable way, i.e., that bio-energy exports can contribute to rural development, benefit local communities and be an integral part of overall development schemes, including the existing agricultural and forestry sectors.

In this paper the links between international bio-energy trade and socio-economic development and how sustainable bio-energy production could be realized are discussed. Drivers, barriers and future potentials for international bio-energy markets are discussed and socio-economic implications for possible exporting countries are explored.

This discussion paper is partly based on a workshop organized by Task 40 under the Bio-energy Agreement of the International Energy Agency on Sustainable International Bio-energy Trade, Task 29 on Socio-Economic Drivers in Implementing Bioenergy Projects, and the Energy and Poverty Thematic Group of the World Bank. This workshop was hosted by the World Bank during the Energy Week in March 2005.

Besides an overview of expertise on areas dealt with by the respective networks and organisations, a key element of the workshop was to discuss in a round-table setting how projects involving development of rural areas and biomass production could be realised and organised.

More information on IEA Task 40 and details on the workshop and other events can be found at www.bioenergytrade.org and on IEA Task 29 at http://www.iea-bioenergy-task29.hr/.

2. Emerging international bio-energy markets: developments and perspectives

2.1. Trends and drivers

Many trade flows take place between neighbouring regions or countries, but trade is increasingly being conducted over long distances. Examples are export of ethanol from Brazil to Japan, the EU and the USA, palm kernel shells from Malaysia to the Netherlands, and wood pellets from Canada to Sweden. This is happening despite the greater bulk and lower calorific value of most biomass raw material. These trade flows may offer multiple benefits for both exporting and importing countries. For example, exporting countries may gain an interesting source of additional income and an increase in employment. Current driving forces and rationales behind the development of trade in bio-energy are diverse, though. They can be structured as described below. (See also [Faaij et al., 2005; Junginger and Faaij, 2005].) In most cases the following factors appear in combination.

1. *Raw material/biomass push.* These drivers are found in most countries with surplus of biomass resources. Ethanol export from Brazil and wood pellet export from Canada are examples of successful push strategies.
2. *Market pull.* Import to the Netherlands is facilitated by the very suitable structure of the leading big utilities. This makes efficient transport and handling possible and leads to low fuel costs compared to those available to users in other countries where the conditions are less favourable.
3. *Utilizing the established logistics of existing trade.* Most of the bio-energy trade between countries in Northern Europe is conducted in integration with the trade in forest products. The most obvious example is bark, sawdust and other residues from imported roundwood. However, other types of integration have

also supported bio-energy trade, such as use of ports and storage facilities, organizational integration, and other factors that kept transaction costs low even in the initial phases. Import of residues from food industries to the UK and the Netherlands are other examples in this field.

4. *Effects of incentives and support institutions.* The introduction of incentives based on political decisions has increased the strength of the driving forces and triggered an expansion of bio-energy trade. However, the pattern has proved to be very different in the various cases, due partly to the nature of other factors, partly to the fact that the institutions related to the incentives are different. It seems obvious that institutions fostering general and free markets, e.g., CO_2 taxes on fossil fuels, are more successful than specific and time-restricted support measures.
5. *Entrepreneurs and innovators.* In countries such as Austria and Sweden, individual entrepreneurs and innovators have had a leading role in the development of bio-energy trade. This has led to a more diversified pattern compared to that in, e.g., Finland, where bio-energy is handled by mature industries, especially within the forestry sector.
6. *Unexpected opportunities.* Storms, forest fires, insect attacks, etc., may lead to short-term imbalances in the supply. Technical failures and other reasons for shut-down cause disturbance in the user and in distribution systems. Such short-term opportunities have often led to new trade patterns, some of which may remain even when the conditions return to normal. For example, last year's hurricanes in the eastern part of the USA led to a short-term trade in wood chips to Europe. Probably this will also occur after the recent hurricanes of September 2005.

For market parties such as utilities, companies providing transport fuels, and parties involved in biomass production and supply (such as forestry companies), good understanding, clear criteria and identification of promising possibilities and areas are of key interest. Investments in infrastructure and conversion capacity rely on minimization of risks of supply disruptions (in terms of volume, quality and price).

2.2. Perspectives and potentials

This section focuses on the potential availability of biomass resources for energy and materials. It briefly discusses the various resource categories: residues from forestry and agriculture, various organic waste streams and, most important, the possibilities for active biomass production on various land categories (e.g., for wood plantations or energy crops such as sugar cane).

2.2.1. Biomass residues and organic wastes

Residues from agriculture: estimates are available from various studies. Potential depends on yield/product ratios and the total agricultural land area and type of production system. Less intensive management systems require re-use of residues for maintaining soil fertility. Intensively-managed systems allow for higher utilisation rates of residues but also usually deploy crops with lower crop-to-residue ratios.

Estimates vary between some 15 and 70 EJ per year. The latter figure is based on the regional *production* of food (in 2003) multiplied by harvesting or processing factors and the assumed recoverability factors. The potential alternative use for agricultural residues is not subtracted from these figures. As indicated by Junginger et al. [2001], competing applications can reduce the net availability of agricultural residues for energy or materials significantly.

Dung: this category especially concerns the use of dried dung. Total estimated contribution could be 5-55 EJ worldwide. The low estimate is based on global current use, the high estimate is the technical potential. Utilisation (collection) in the longer term is uncertain because this is particularly considered a poor man's fuel.

Organic wastes: this category includes the organic fraction of municipal solid waste (MSW) and waste wood (e.g., demolition wood). Estimates on the basis of literature are strongly dependent on assumptions on economic development, consumption and the use of bio-materials; the ranges projected for MSW in the longer term (e.g., beyond 2040) amount to 5-50 EJ. Higher values are possible when more intensive use is made of bio-materials.

Forest residues: the (sustainable) energy potential of the world's forests is partly uncertain. A recent evaluation of forest reserves and development of demand for wood products concluded that even in the case of the highest wood demand projections found in the literature, the demand can (in theory) be met without further deforestation. The bio-energy potential from forestry can contribute 1-98 EJ/year of surplus natural forest growth and 32-52 EJ/year harvesting and processing residues in 2050. The most promising regions are the Caribbean and Latin America, the former Soviet Union and, partly, North America. Key variables are the demand for industrial roundwood and fuel-wood, plantation establishment rates, natural forest growth and the impact of technology and recycling.

2.2.2. The potential for energy crops

Clearly, active biomass production requires land. The potential for energy crops therefore largely depends on land availability, considering that, worldwide, a growing demand for food has to be met, combined with nature protection, sustainable management of soils and water resources and a variety of other sustainability criteria. Given that a major part of the future biomass resource availability for energy and materials depends on these (intertwined, uncertain and partially policy-dependent) factors, it is impossible to present the future biomass potential in one simple figure. A review of available studies of future biomass availability carried out in 2002 (17 in all) revealed that no complete integrated assessment and scenario studies were available then [Berndes et al., 2003]. These studies were carried out for and by, amongst others: the Intergovernmental Panel on Climate Change (IPCC), US Environment Protection Agency (EPA), World Energy Council, Shell, and the Stockholm Environmental Institute.

The studies arrived at varying conclusions about the possible contribution of biomass to the future global energy supply (e.g., from below 100 EJ/yr to above 400 EJ/yr in 2050). The major reason for the differences is that the two most crucial parameters – land availability and yield levels in energy crop production – are very uncertain, and subject to widely different opinions (e.g., the assessed 2050 plantation supply ranges from below 50 EJ/yr to almost 240 EJ/yr). However, the expectations about future availability of forest wood and of residues from agriculture and forestry also vary substantially among the studies.

The question of how an expanding bio-energy sector would interact with other land uses, such as food production, biodiversity, soil and nature conservation, and carbon sequestration has been insufficiently analysed in the studies. A refined modelling of interactions between different uses and bio-energy, food and materials production – i.e., of competition for resources, and of synergies between different uses – would facilitate an improved understanding of the prospects for large-scale bio-energy in the future.

Recently, these issues were addressed in several studies. One approach is reported in [Smeets et al., 2004], where bottom-up information was used on land use, agricultural management systems on a country-by-country basis, projections for demand for food, and information on possible improvements in agricultural management (for both crops and production of meat and dairy products). Another important study was carried out by Hoogwijk [Hoogwijk et al., 2005; Hoogwijk, 2004] which used integrated assessment modelling to evaluate future biomass potentials for different scenarios from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES).

2.2.3. Synthesis of findings on long-term global biomass potentials

Summarizing, both the technical and economic potential of biomass resources for energy and material use can be very large, up to over twice the current global energy demand, without competing with food production, protection of forests and nature. Besides residues from agriculture and forestry (which are significant, but also limited due to competing applications) and organic waste, especially active production (e.g., energy crops) of biomass is responsible for these potentials. Key, however, to the development of competitive energy cropping systems is the rationalization of agriculture, especially in developing countries, which can result in considerably higher land-use efficiencies for agriculture and thus a surplus of productive land. Perennial crops (such as eucalyptus, poplar, and grasses such as miscanthus and sugar cane) provide the most favourable economic and environmental characteristics for biomass production. Table 1 (based on [Faaij et al., 2000; Smeets et al., 2004; Hoogwijk et al., 2005; 2003]) provides a summary of the biomass categories discussed in this section.

In theory, energy farming on current agricultural land could, with projected technological progress, contribute over 800 EJ, without jeopardising the world's food supply. Organic wastes and residues could possibly supply another 40-170 EJ, with uncertain contributions from forest residues and potentially a very significant role for organic waste, especially when bio-materials are used on a larger scale [Smeets and Faaij, 2006]. In total, the upper limit of bio-energy potential could be over 1000 EJ (per year). This is considerably more than the current global energy use of about 430 EJ.

Latin America, Sub-Saharan Africa and Eastern Europe clearly are promising regions, also Oceania and East and North-East Asia jump out as potential biomass production areas in the longer term. The latter can in particular be explained by the projected demographic developments (possibly declining population in China after 2030) and fast technological progress in agriculture, leading to substantial productivity increases. These analyses also show that a large part of the technical potential for biomass production may be developed at low production costs in the range of US$ 2/GJ [Hoogwijk, 2004; Rogner et al., 2000].

Major transitions are however required to exploit this bio-energy potential. Improving agricultural efficiency in developing countries (i.e., increasing crop yields per hectare) is especially a key factor. It is still uncertain to what extent and how fast such transitions can be realized in different regions. Under less favourable conditions, the (regional) bio-energy potential(s) could be quite low. Also, it should be noted that technological developments (in conversion) and long-distance biomass supply chains (i.e., comprising intercontinental transport of biomass-derived energy carriers) can dramatically improve the competitiveness and efficiency of bio-energy [Faaij, 2006; Hamelinck et al., 2005]. Increased competitiveness is logically a driver to develop the production potentials of bio-energy.

2.2.4. Critical issues

The message from recent analyses that address global biomass potentials in the long term is a complex one: technical and even economic potentials can be very large and could make biomass a fundamental alternative to oil during this century. However, those potentials need to be developed to a large extent. Available residues and organic wastes from agriculture, forestry and the waste treatment sector are substantial, but also limited. The (sustainable) use of different types of land (marginal and degraded, and good quality agricultural and pasture land) depends on the success of accelerating the improvements in current agricultural management and integrating biomass production in a sustainable way in current land-use patterns. Our understanding of how this can be achieved from region to region is often limited. Current experience with energy crops such as willow (in Sweden) and sugar cane (in Brazil) gives indications of how biomass production can gradually be introduced in agriculture and forestry. In developing countries (e.g., in Sub-Saharan Africa) very large improvements can be made in agricultural productivity given the current agricultural methods deployed (often subsistence farming), but better and more efficient agricultural methods will not be implemented without investments and proper capacity-building and infrastructure improvements. Much more experience is needed with such schemes, in which the introduction of bio-energy can play a pivotal role to create more income for rural regions through the additional bio-energy production. Financial resources generated could then accelerate investments in

Table 1. Overview of the global potential bio-energy supply in the long term for a number of categories and the main preconditions and assumptions that determine these potentials

Biomass category	Main assumptions and remarks	Potential bio-energy supply up to 2050 (EJ/yr)[1]
Energy farming on current agricultural land	Potential land surplus: 0-4 Gha (more average: 1-2 Gha). A large surplus requires structural adaptation of intensive agricultural production systems. When this is not feasible, the bio-energy potential could be reduced to zero as well. On average higher yields are likely because of better soil quality: 8-12 dry t/ha/yr is assumed[2].	0-700 (100-300)
Biomass production on marginal lands	On a global scale a maximum land surface of 1.7 Gha could be involved. Low productivity of 2-5 dry t/ha/yr[2]. The supply could be low or zero due to poor economics or competition with food production.	0-150 (60–150)
Bio-materials	Range of the land area required to meet the additional global demand for bio-materials: 0.2-0.8 Gha (average productivity: 5 dry t/ha/yr). This demand should be come from Category I and II in case the world's forests are unable to meet the additional demand. If they are, however, the claim on (agricultural) land could be zero.	0-150 (40-150)[3]
Residues from agriculture	Estimates from various studies. Potential depends on yield/product ratios and the total agricultural land area and type of production system: extensive production systems require re-use of residues for maintaining soil fertility. Intensive systems allow for higher utilisation rates of residues.	15-70
Forest residues	The (sustainable) energy potential of the world's forests is unclear. Part is natural forest (reserves). Range is based on literature data. Low value: figure for sustainable forest management. High value: technical potential. Figures include processing residues.	0-150 (30-150)
Dung	Use of dried dung. Low estimate based on global current use. High estimate: technical potential. Utilisation (collection) in longer term is uncertain.	0-55 (5-55)
Organic wastes	Estimate on basis of literature values. Strongly dependent on economic development, consumption and the use of bio-materials. Figures include the organic fraction of MSW and waste wood. Higher values possible by more intensive use of bio-materials.	5-50+[4]
Total	Most pessimistic scenario: no land available for energy farming; only utilisation of residues. Most optimistic scenario: intensive agriculture concentrated on the better quality soils.	40-1100 (250-500)

Notes

1. Where two ranges are given, numbers between brackets give the range of average potential in a world aiming for large-scale utilisation of biomass. A lower limit of zero implies that potential availability could be zero, e.g., if we fail to modernize agriculture so that more land is needed to feed the world.
2. Heating value: 19 GJ/t dry matter.
3. This value could even be negative: the potential biomass demand for producing bio-materials (such as bio-plastics or construction materials). These markets can represent a large demand for biomass that will reduce the availability of biomass for energy. However, the more bio-materials are used the more organic waste (eventually) will become available for energy. Such use of biomass results in a "double" GHG benefit as well through avoided emissions in manufacturing materials with fossil fuels and by producing energy from the waste. Thus, calculating the potential biomass availability for energy is not straightforward adding the figures of the different rows. More details are given in [Hoogwijk et al., 2003].
4. The energy supply of bio-materials ending up as waste can vary between 20 and 55 EJ (or 1100-2900 Mt dry matter) per year. This range excludes cascading and does not take into account the time delay between production of the material and "release" as (organic) waste.

conventional agriculture and infrastructure and also lead to improved management of agricultural land.

The critical issues that require further research and especially more regional demonstrations and experience with biomass production are listed below.

2.2.4.1. Competition for water resources

Water is logically a critical resource for both food and biomass production and a constrained resource in many world regions. Water scarcity in relation to additional biomass production has been addressed to a limited extent. Berndes [2002] explains that there are major expectations that bio-energy will supply large amounts of CO_2-neutral energy for the future. A large-scale expansion of energy crop production would lead to a large increase in evapo-transpiration appropriation for human uses, potentially as large as the present evapo-transpiration from global cropland. In some countries this could lead to further aggravation of already existing water shortage. But there are also countries where such impacts are less likely to occur. One major conclusion for future research is that assessments of bio-energy potentials need to consider restrictions from competing demand for water resources.

2.2.4.2. Availability of fertilisers and pest control

Increases in agricultural productivity, in particular in developing countries, can only be achieved when better management and higher productivities are achieved. This implies availability of fertilisers and pest control methods. Their use needs to be within sound limits. Sound agricultural methods (agro-forestry, precision farming, biological pest control, etc.) exist that can achieve major increases in productivity with neutral or even positive environmental impacts. Such practices must however be secured by sufficient knowledge, funds and human capacity and knowledge.

2.2.4.3. Land-use planning taking bio-diversity and soil quality into account

Criticism is raised by various new analyses (Milieu & NatuurPlanbureau i.e., the Netherlands Environmental Assessment Agency, European Environment Agency) that further intensification of agriculture and large-scale production of biomass energy crops may result in losses of biodiversity compared to current land use, even when international standards for nature protection (10-20 % of land reserved for nature) are respected [Smeets et al., 2004]. Biodiversity standards are to be interconnected with biomass production even when changes in land use are considered. The fact is that perennial crops (which are the preferred category of crops for energy production) have a (much) better ecological profile than annual crops and benefits with respect to biodiversity can be achieved when perennial crops displace annual crops. However, insights into how biodiversity effects can be optimised (and improved compared to current land use) when sound landscape planning is introduced are limited. Some indications are given by experiences in Sweden and the UK with the integration of willow production on landscape level with overall positive effects. São Paulo state in Brazil has strict standards for sugar cane production areas and for original vegetation that do not necessarily lead to a loss in biodiversity. Also here, more regional efforts, experience and specific solutions are needed.

2.2.4.4. The use and conversion of pasture land connected to more intensive methods of cattle-raising

A key land category in making more efficient use of land for food production are the worlds's grasslands now used for grazing. The analyses carried out here show that much land can be released when production of meat and dairy products is done in more intensive schemes (partly landless, in closed stalls). Grasslands could then be used for production of energy grasses or partly converted to woodlands. Such changes in land-use functions have so far been poorly studied, although similar conversion takes place in, for example, Brazil. The impacts of such changes should be closely evaluated.

2.2.4.5. Socio-economic impacts – in particular in rural regions

Large-scale production of modern biofuels, partly for the export market, could provide a major opportunity for many rural regions around the world to generate major economic activity, income and employment. Given the size of the global market for transport fuels, the benefits that can be achieved by reducing oil imports and possibly making net exports of bio-energy are vast. Nevertheless, it is not a given that those benefits end up with the rural population and farmers that need those benefits most. Also, the net impacts for a region as a whole, including possible changes and improvements in agricultural production methods, should be kept in mind when developing biomass and biofuel production capacity. Although various experiences around the globe (World Bank activities/ projects in Africa; Brazil, India) with biofuels show that major socio-economic benefits can be achieved, new biofuel production schemes should ensure the involvement of the regional stakeholders, in particular the farmers. Experience with such schemes needs to be built around the globe.

2.2.4.6. Macroeconomic impacts of changes in land-use patterns

Although these analyses indicate that both the world's food demand and additional biomass production *can* (under relevant preconditions) be achieved, more intensive land use and additional land use for biomass production may lead to macroeconomic effects on land and food prices. Although this is not necessarily a bad mechanism (it could be vital for farmers to enable investment in current production methods), the possible implications on the macroeconomic level are poorly understood. More analyses are needed that can highlight with what speed of implementation and change undesired economic effects can be avoided.

2.3. Barriers

On the basis of literature review and interviews, a number of potential barrier categories have been identified. These barriers may vary a great deal in terms of scope, relevance for exporting and importing countries and how stakeholders perceive the trade. A summary of the main barriers is given below (see also [Faaij et al., 2005; Junginger and Faaij, 2005]).

Economic barriers

- Competition with fossil fuel on a direct production cost basis (excluding externalities). For example the market price in 2004 for biomass pellets in the Netherlands was about 7-7.5 Euro/GJ, and is expected to stabilize around 5.6-6.4 in the short term, while the cost of coal remains generally about 1.2 Euro/GJ. On the other hand, current production costs lie between US$ 1 and 2/GJ in Brazil. Thus, the high prices seem to be caused by a current constraint on the supply side.
- In order to promote bio-energy many developed and some developing countries have stimulated the development and use of biomass for electricity, heat and transportation by the introduction of different measures, e.g., governmental RD&D programmes, tax cuts and exemptions, investment subsidies, feed-in tariffs for renewable electricity, mandatory blending for biofuels or biofuel quotas. However, an often-heard criticism from the market side is that these measures may not be sufficient (e.g., there is no mandatory target for the EU-25 biofuels directive), since they are mostly temporary and tend to change frequently. This discourages long-term investment, as it is considered too risky.
- Due to the size, often small, of bio-energy markets and the fact that biomass by-products are a relatively new commodity in many countries, markets can be immature and unstable. This makes it difficult to sign long-term, large-volume contracts, as doing so is seen as too risky. Also, with no harmonised support policy (e.g., on a EU level), new national incentives (and associated demand for bio-energy) may distort the market and shift supply to other countries within a short time-frame. Due to expected increasing international competition Dutch traders expect a growing demand for cheap biomass streams in the mid-term (5-10 years) both in developed and developing countries due to expected local demand.

Technical barriers

A general problem with many types of biomass is its physical and chemical properties such as low density, high ash and moisture content, and nitrogen, sulphur or chlorine content, making it difficult and expensive to transport and often unsuitable for direct use, say for co-firing with coal or natural gas power plants.

Power producers are generally reluctant to experiment with new biomass streams, e.g., bagasse or rice husk. As these streams often do not have the required physical and chemical properties, power producers are afraid to damage their installations (designed for fossil fuels), especially their boilers. While technology is available to deal with the fuels (e.g., different types of fluidized bed boilers), it may take several years or even decades before the old capacity is replaced.

In the longer term, the limited ability to use different fuels may lead to a restricted availability of biomass fuels.

Logistical barriers

- There is a lack of technically mature pre-treatment technologies for compacting biomass at low cost to facilitate transportation, although this is fortunately improving. Densification technology has improved significantly recently, e.g., for pellets, although this technology is only suitable for certain biomass types. Also, the final density is still far less than that of, e.g., oil or coal, given the nature of biomass. Pyrolysis or torrefaction may be a possible pre-treatment option, but it still needs to be proven on a commercial scale. In the case of the import of liquid biofuels (e.g., ethanol, vegetable oils, bio-diesel), this is not an issue, as the energy density of these biofuels is relatively high.
- Various studies have shown that long-distance international transport by ship is feasible in terms of energy use and transportation *costs* (see below) but availability of suitable vessels and meteorological conditions (e.g., winter time in Scandinavia and Russia) need be considered.
- Local transportation by truck (in both biomass exporting and importing countries) may be a high cost factor, which can influence the overall energy balance and total biomass costs. For example, in Brazil, new sugar cane plantations are being considered in the Centre-West, but the cost of transport and lack of infrastructure can be a serious constraint. Harbour and terminal suitability to handle large biomass streams can also hinder the import and export of biomass from and to certain regions. The most favourable situation is when the end-user has the facility close to the harbour, avoiding additional transport by trucks.
- The lack of significant volumes of biomass can also hamper logistics. In order to achieve low costs, large volumes need to be shipped on a more regular basis. Only if this can be assured will investment be forthcoming on the supply side (e.g., new biomass pellet factories) as this will reduce costs significantly.

International trade barriers

- A lack of clear technical specifications for biomass (see above) and specific biomass import regulations. This can be a major hindrance to trading. For example, in the EU most residues that contain traces of starches are considered potential animal fodder and are thus subject to EU import levies. For example, rice residues containing 0-35 % starch are taxed at 44 Euro/t (i.e. about 3.1 Euro/GJ). For denaturised ethanol of 80 % concentration and above, the import levy is 102 Euro/m^3 (i.e., about 4.9 Euro/GJ), representing substantial additional costs. Other biomass streams such as wood pellets are currently exempted in the EU. It is important to bear in mind that some technical trade barriers can be, in fact, imposed to constrain imports and to protect local producers.
- Transport tariffs. In recent years, general transport tariffs have increased quite significantly, e.g., transport for wood pellets to the Netherlands cost on average 1.75 Euro/GJ (on a total cost of 7-7.5 Euro) in 2004.
- Possible contamination of imported biomass with pathogens or pests (e.g., insects, fungi) can be another important limiting factor in international trade. For example, roundwood from outside the EU can currently be rejected for import to Finland (for the whole of the EU) if it is contaminated with pests. Similarly, agricultural residues which could be used both as fodder and biomass may currently be denied entry if they do not meet certain fodder requirements. However, it is important to bear in mind that these limitations are not exclusive to bio-energy.

Land availability, deforestation and potential conflict with food production

- Competition for land: while theoretically large areas of (abandoned/degraded) cropland are available for biomass cultivation, biomass production costs are generally higher due to lower yields and accessibility difficulties. Deforested areas may be easier as they may have more productive soil, but are generally considered unsustainable in the long term. Food security, i.e., production and access to food, would probably not be affected by large energy plantations if proper management and policies are put in place. However, in practice food availability is not the problem, but the lack of purchasing power of the poorer strata of the population.
- In developed countries, a key issue is competition with fodder production. If there was a large increase in demand for energy, say of agricultural residues, scarcity of fodder products may occur, leading to a price increase. Furthermore, in the Netherlands, the fodder industry sees the feed-in tariff for electricity from biomass as an indirect subsidy for agro-residue. On the other hand, the fodder market is also subsidized.

Sustainability issues

- Large-scale biomass-dedicated energy plantations also pose various ecological and environmental issues that cannot be ignored, including long-term monoculture sustainability, potential loss of biodiversity, soil erosion, freshwater use, nutrient leaching and pollution from chemicals. However, various studies have also shown that in general these problems are less serious when compared with similar plantations for food or fodder production.
- Also linked to potential large-scale energy plantations are the social implications, e.g., the effect on the quality of employment (which may increase, or decrease,

depending on the level of mechanization, local conditions, etc.), potential use of child labour, education and access to health care. However, such implications will reflect prevailing situations and would not necessarily be better or worse than for any other similar activity.

Methodological barriers – lack of clear international accounting rules

- A lack of clear rules and standards for, e.g., allocation of GHG credits and the related issue of methodologies to be used to evaluate the avoided emissions, considering the fuel life-cycle (see also [Schlamadinger et al., 2005]).
- Another issue is the indirect import of biomass for energy (processed biomass). Biomass trade can be considered a direct trade in fuel and indirect flow of raw materials that end up as fuels in energy production during or after the production process of the main product. For example, in Finland the biggest international biomass trade volume is indirect trade in roundwood and wood chips. Roundwood is used as raw material in timber or pulp production. Wood chips are raw material for pulp production. One of the waste products of the pulp and paper industry is black liquor, which is used for energy production.

Legal (national) barriers

Biomass for energy may be limited by international environmental laws. For example, in the Netherlands, four out of five major biomass power producers consider obtaining emission permits one of the major obstacles for further deployment of various biomass streams for electricity production. The main problem is that Dutch emission standards do not conform to EU emission standards. In several cases in 2003 and 2004, permits given by local authorities have been declared invalid by Dutch courts.

Summarizing, although international bio-energy trade and markets are developing very rapidly and the future looks bright, given market demand and potential supplies, many barriers also exist that can disturb or at least slow down a sound development of such markets. Also, there are important concerns about competition for land that may conflict with food production, water resources and biodiversity protection. Although biomass production may well provide a crucial strategy to enhance sustainable land-use management, negative developments should be avoided, e.g., by clear standards and best-practice guidelines for (the design of) biomass production systems and their integration in agricultural areas. A key question in this respect is if, and if yes then to what extent, biomass production, for export and in a global setting, can provide a positive driver for (rural) development, in particular in developing countries. This is discussed in the following section.

3. The socio-economic impacts of bio-energy development

3.1. Socio-economic drivers for bio-energy use

Biomass utilisation, bio-energy technologies, their market share and research interests vary considerably between different countries. Nevertheless, in most countries socio-economic benefits of bio-energy use can clearly be identified as a very significant driving force in increasing the share of bio-energy in the total energy supply. In most countries regional employment created and economic gains are probably the two most important issues addressed when considering biomass use for energy production.

Bio-energy has provided millions of households with incomes, livelihood activities and employment. The essence of sustainability of bio-energy projects from a social aspect is how they are perceived by society, and how different societies benefit from this activity in different ways. Other "big issues" such as mitigating carbon emissions, ensuring wider environmental protection and providing security of energy supply are an added bonus for local communities where the primary driving force is much more likely to be related to employment or job creation. Overall, these benefits will result in increased social cohesion and create greater social stability.

For the public, policy-makers and decision-makers, energy and bio-energy are becoming increasingly interesting and important subjects as a result of rises in the prices and more insecure supplies of fossil fuels. Enhanced environmental concerns are encouraging the use of alternative and renewable sources of energy, particularly in developed countries. Governments are also responding more and more to the Kyoto Protocol.

Socio-economic impact studies are commonly used to evaluate the local, regional and/or national implications of implementing particular development decisions. Typically, these implications are measured in terms of economic indices, such as employment and financial gains, but in effect the analysis relates to a number of aspects, which include social, cultural and environmental issues. A complication lies in the fact that these latter elements are not always tractable to quantitative analysis and, therefore, have been excluded from the majority of impact assessments in the past, even though at the local level they may be very significant (Table 2).

The increased use of bio-energy has stimulated a revival of cultural traditions. In the boreal forest, many remote communities have no year-round road or connections to electricity grids, and are dependent on diesel generators supplied by fuel flown or barged in at high cost. These communities are often surrounded by forest that could provide the necessary biomass for energy generation, making the community more self-sufficient, reduce costs, provide employment, and integrate well with a forest-based culture. There are examples where a shift to locally-produced bio-energy has been very successful and these successes need to be communicated and fostered.

The varied nature of biomass and the many possible routes for converting the biomass resource to useful energy make this topic a complex subject. When we talk about sources of biomass we need to consider forestry, agriculture, industrial residues, short rotation coppice plantations, communal waste, urban biomass, etc. This involves a combination of different economic sectors and human activities and consequently is often not well understood.

Diffusion of technologies in general, and the use of

Table 2. Selected indicators of socio-economic sustainability within the context of modernised biomass energy for sustainable development [Kartha and Larson, 2000]

Category	Impact	Quantitative indicators
Basic needs	Improved access to basic services	Number of families with access to energy services (cooking fuel, pumped water, electric lighting, milling etc.), quality, reliability, accessibility, cost
Income-generating opportunities	Creation or displacement of jobs, livelihoods	Volume of industry and small-scale enterprise promoted, jobs/$ invested, jobs/ha used, salaries, seasonality, accessibility for local labour force, local recycling of revenue (through wages, local expenditures, taxes), development of markets for local farm and non-farm products
Gender	Impacts on labour, power, access to resources	Relative access to outputs of bio-energy project, decision-making responsibility both within and outside of bio-energy project, changes to former division of labour, access to resources relating to bio-energy activities
Land-use competition and land tenure	Changing patterns of land ownership, altered access to common land resources, emerging local and macroeconomic competition with other land uses	Recent ownership patterns and trends (e.g., consolidation or distribution of landholdings, privatisation, common enclosures, transfer of land rights/free rights), price effects on alternative products, simultaneous land uses (e.g., multipurpose crop production of other outputs such as traditional biofuel, fodder, food, animal products, etc.)

bio-energy in particular, does not depend on technological advances and favourable economic conditions alone. A good understanding and strong backing of bio-energy by the wider public are essential to encourage policies supporting the introduction and wider use of bio-energy but would also help to bring costs further down as a result of increased adoption rates and economies of scale. Similarly, a lack of awareness may result in resistance to bio-energy projects, even if they are economically viable and technologically robust.

3.2. The socio-economic impacts and benefits of bio-energy development

Bio-energy can contribute to many important elements of national or regional development: economic growth through business expansion and employment; import substitution (direct and indirect economic effects on GDP and trade balance); security of energy supply; and energy source diversification.

The increased use of bio-energy, which exhibits both a broad geographical distribution, and diversity of feedstock, could secure long-term access to energy supplies at relatively constant costs. A frequently mentioned obstacle to the expansion and acceptance of bio-energy into world energy markets is that the markets do not acknowledge the real costs and risks connected with the usage of fossil and nuclear fuels. To provide a fair comparison of the price of fuels, all of the so-called “externalities” should be internalized into calculations, be they benefits or costs. The expense of maintaining channels to fossil fuel sources through military means should also to be taken into consideration.

In addition to its local benefits, biomass has macroeconomic advantages for countries which use it – security of supply and an improved balance of trade for fuel-importing countries. The growing dependence of the European Union on imported oil has influenced several legislative initiatives (directives) intended to faciliate the development of biofuel markets in Europe. The EC Green Paper *Towards a European Strategy for the Security of Energy Supply* emphasized the importance of energy independence and the possible role of bio-energy and other renewable energy sources in overcoming increasing external dependence. Among other solutions and proposed actions, the paper proposes to adapt the existing fiscal framework for renewable energy sources. This should enable bio-energy to benefit from preferential conditions, allowing it to become competitive with other energy sources.

What can the bio-energy sector offer in terms of employment generation? Global scenarios differ. Most developing countries continue to use bio-energy in the traditional way but the unprecedented population growth in these regions is depleting existing resources. Developed countries, on the other hand, continue to invest in RD&D to further the advancement of bio-energy technology. International commitments provide further leverage to cut carbon emissions, push technological frontiers and encourage the use of better and more environmentally appropriate fuels in the years to come. Global climate change coupled with the intertwined realities of social, political, economic and environmental issues poses many challenges and opportunities to come.

At present, approximately 10 % of the world’s primary energy is derived from biomass used in developing countries, often in the traditional ways. However, this practice is unsustainable as the unprecedented population growth in these regions is depleting existing resources. Furthermore, much of it is used inefficiently and in polluting ways, exposing hundreds of millions of people to intolerably high levels of pollution from cooking and heating. In addition, these people spend many hours a day collecting and carrying fuel, instead of spending this time in more productive ways. One option is to provide them with access to cleaner fuels and to electricity for cooking and for pumping water. In addition, this may also provide them with a source of income, assuming that they would grow their own energy crops or use the existing biomass in a more energy-efficient way.

Modern biomass systems are clean, efficient and safe. Application of such systems can also facilitate social changes by increasing biomass-based employment in

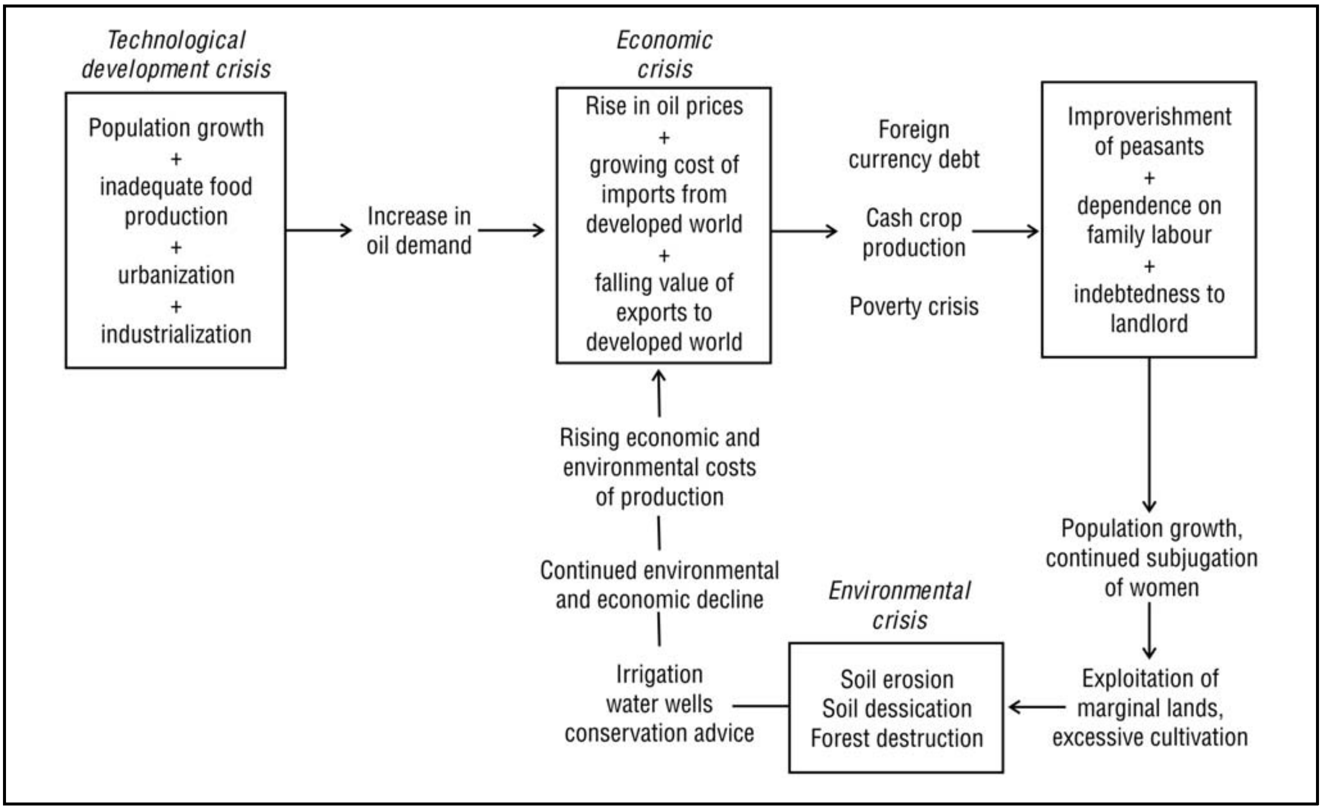

Figure 1. The crisis of sustainability in developing countries [Wereko-Brobby and Hagen, 1996]

developing countries. It is obviously very different to work as a wood energy producer in a poor developing country than in Europe or the USA. Employment in the biomass sector can imply low wages/ training/ capacity. The fact that more people are needed per energy unit produced is not necessarily a positive matter. Many biomass energy workers in developing countries would like to have other opportunities of employment to move up the "economic ladder". A comparison of the wages in both developing and developed countries shows that in developed countries the wood energy worker earns the equivalent of many other technically qualified workers and can have an average life-style. In developing countries the wood energy worker will probably earn well below an average wage and fit in the lowest economic level. It may therefore be desirable to encourage the use of modern bio-energy systems in developing countries at the cost of losing some jobs but raising economic standards for those remaining.

In Europe, policy-makers recognise that there are economic benefits from renewables (in this case bio-energy), especially in terms of employment and the development of a strong export industry. The renewable energy industry is one of Europe's fastest growing sectors as member-states encourage the deployment of renewables as an alternative, indigenous energy source with low environmental impacts [Domac et al., 2005].

3.3. International bio-energy trade as a driver for (sustainable) development?

Could international bio-energy trade really be a driver for sustainable development? Figure 1 depicts the relations that (currently) exist between economic growth and population growth, subsequent increasing demands for energy, trade balances of developing countries, impacts on rural communities and subsequent environmental degradation. Many developing regions have ended up in a downward spiral similar to the scheme shown.

Bio-energy is right in the middle of these relations. Modern biomass and bio-energy are not a silver bullet that can solve all these problems and could, when wrongly managed, even aggravate some of the problems mentioned. However, it seems to be one of the few available strategies and options that can, when implemented and developed in the right way and suited to regional conditions, reverse many of the downward trends. The market size for bio-energy (virtually unlimited on an international scale), the fact that it can directly replace oil (through biofuels for transport), the possibilities for crop production with positive ecological impacts with respect to soil regeneration, biodiversity and emissions of agrochemicals, and the fact that biomass production and supply chains can be fully operated in rural economies (in contrast to many other alternative energy options), maximizing the value added for this part of the economy, make it a potential backbone of broader sustainable development schemes. The inherent economic value of carbon-neutral, renewable fuel on the world market may provide the economic engine for rural regions that now often lack any export possibilities to finance development and modernization of agriculture together.

There are already examples of how international bio-energy trade can act as a driver for development. There are many promising experiences of modern biomass in developed countries and some promising experiences in developing countries.

One recent example is the Colombian programme to produce bio-ethanol from sugar cane which has begun following the introduction of a law which mandates the use of 10 % ethanol blends in petrol, starting this year. This will mean the manufacture of 2–2.5 Ml of bio-ethanol per day, which will be produced in several agro-industrial facilities around the country. It is estimated that this programme will require the cultivation of an additional 150,000 ha of sugar cane, resulting in 170,000 new jobs. In addition, under this project each farming family will have an increased salary (2-3 times) and therefore the opportunity for an improved quality of life, compared with the present situation (average per capita Colombian income is about US$ 1500 per year). The programme will result in bio-ethanol sales of the order of $ 400 million per year, of which around $ 240 million will go to the sugar cane business. New fuel production will substitute fuel imports of around $ 130 million per year and the agro-GDP will be increased by 3 %. It is hoped that this will help to stimulate regional rural development [Janssen, 2004].

Another example is the PRO-ALCOOL programme in Brazil. The programme also displays many of the benefits of "sustainability" – the raw material is renewable and it is locally produced, reducing transport and foreign exchange spending on oil imports. In addition, ethanol is superior to petrol from an environmental perspective and the production of sugar cane-derived ethanol provides rural development benefits (around 700,000 jobs have been created). The overall sustainability is, however, still being questioned by various environmental groups, with the main issue being how the arable land for ethanol production is ensured [Carpentieri et al., 1993].

The possibilities of exporting biomass-derived commodities for the world's energy market can provide a stable and reliable demand for rural communities particularly in many developing countries, thus creating an important incentive and market access in many areas in the world. In the past decade such trade flows have been increasing rapidly. Many trade flows are between neighbouring countries, but increasingly, long-distance trade is also occurring. Examples are export of ethanol from Brazil to Japan and the EU, palm kernel shells (a residue of the palm oil production process) from Malaysia to the Netherlands, and wood pellets from Canada to Sweden. These trade flows may offer multiple benefits for both exporting and importing countries. For example, exporting countries may gain an interesting source of additional income and an increase in employment. Also, sustainable biomass production will contribute to the sustainable management of natural resources. Importing countries on the other hand may be able to cost-effectively meet their GHG emission reduction targets and diversify their fuel-mix.

4. Closing remarks

Bio-energy continues to make up a significant share of global energy consumption. Modern biomass is developing rapidly. Many new and improved bio-energy technologies are reaching the market and, in some cases, are successfully competing with fossil fuels even without government incentives. Bio-energy in its traditional forms is still the main source of energy in many developing countries, and will continue to be so in the foreseeable future. Bio-energy has often been associated with poor environment and health hazards but these attributes are not inherent to bio-energy but the consequence of underdevelopment, cultural factors and so forth.

Application of modern biomass systems supported by sustainable international trade can facilitate changes in biomass-based employment in developing countries and contribute to their overall development. However, a fair trade concept and complete sustainability are still a big challenge. For example, a comparison of the wages in developing and developed countries would show that in developed countries the wood energy worker earns the equivalent of many other technically qualified workers and can have an average life-style. In developing countries the wood energy worker will probably earn well below an average wage, being left at the lowest economic levels.

This discussion paper has identified opportunities and possible links between international bio-energy trade and the resulting socio-economic benefits of global importance. If indeed the global bio-energy market is to develop to a size of 400 EJ over this century (which is quite possible given the findings of recent global potential assessments) the value of that market at US$ 4/GJ (considering pre-treated biomass such as pellets) amounts to some US$ 1.6 trillion per year. Not all biomass will be traded on international markets logically, but such an indicative estimate makes clear what the economic importance of this market can become for rural regions worldwide, as are the employment implications. Considering that about a quarter of the 400 EJ cited could be covered by residues and wastes, a quarter by regeneration of degraded and marginal lands, and the remaining half by production from current agricultural and pasture lands, some 1 Gha worldwide may be involved in biomass production. This is some 8 % of the global land surface and a fifth of the land currently in use for agricultural production.

However, a number of questions are still open and should be elaborated in the future, while building experience with the growing bio-energy market over time. Below, several important issues are listed.

1. Domestic production vs. import/export

Because biomass use is in particular favoured because of its desired effect of lowering GHG emissions, resources and chains should be favoured (and perhaps certified) that maximize GHG mitigation. This implies minimisation of energy inputs, but also optimisation of the use of biomass, e.g., including comparison between indigenous use versus export.

While many developing countries have a low energy consumption compared to developed countries, their energy demand is increasing rapidly. Should biomass for energy be utilised locally or for export? Should market forces have the last say? For example, Brazil is planning to increase ethanol production enormously over the next eight years, and to start up bio-diesel production from soy beans, palm oil, etc. Only a fraction will be exported; the rest will be used domestically. A similar situation can occur in developed countries, e.g., in Finland, which currently exports to the rest of the EU large volumes of pellets which could also be utilized domestically, the main driver being the different national incentives paid for pellets. In general, it would be more rational to use the biomass primarily locally, and only the (certificated) excess should be exported. However, it should be borne in mind that international competition will force domestic producers to be more competitive.

In addition, bio-diesel production in Western Europe, and ethanol in the EU-25, USA and Canada have been increasing rapidly over the last few years, even though these biofuels are often far more expensive (e.g., twice or three times as much as Brazilian ethanol), and the energy balance may be questionable. This is due to a combination of other factors, e.g., fuel security and employment in the agricultural sector. Therefore, these biofuels are currently subsidized or enjoy fiscal advantages (e.g., tax exemptions) in many countries.

2. Solving sustainability issues: international classification and certification of biomass

Certification of biomass may be one way to prevent negative environmental and social side-effects. By setting up minimum social and ecological standards, and tracing biomass from production to end-use, the sustainability of biomass can be ensured. In an exploratory study it has been shown that such social and environmental standards do not necessarily result in high additional costs [Smeets et al., 2005].

However, when implementing a certification scheme for sustainable bio-energy, several other issues have to be dealt with. Firstly, criteria and indicators need to be designed/adopted according to the requirements of a region. Also, the compliance with the criteria has to be controllable in practice, without incurring high additional costs. Second is avoidance of leakage effects (leakage can be defined as activity-induced changes in land use that occur outside the area in which the activity takes place). The net effect is that carbon benefits gained in one place are partially lost in (leak away) in another location. Leakage in the context of biomass trade could stand for an unwanted shift of activities from the area of biomass production to another area where it leads to negative effects on the environment.

It should be investigated whether an independent international certification body for sustainable biomass is feasible. This should be done by a consortium of all stakeholders in the biomass energy production chain. Probably a gradual development of such a certification scheme is most feasible with gradual learning and expansion over time. Any certification scheme should on the one hand be thorough, comprehensive and reliable, but on the other also not become a barrier to markets in itself.

3. Setting up technical biomass standards

By setting up internationally accepted quality standards for specific biomass streams (e.g., Comité Européen de Normalisation, i.e., European Committee for Standardization, biofuel standards), biomass end-users may have a higher confidence in using different biomass streams. Task 40 may possibly contribute to this, e.g., by collecting information on technical specifications required by consumers and conveying them to potential suppliers. Furthermore, classification of organic matter streams as specific biomass fuel may aid WTO classification as EGS (Environmental Goods and Services).

4. Lowering of trade barriers

Biofuels could help industrialized countries to promote reduction of carbon emissions but in some cases – as is the case of ethanol export to the US and the EU – exporting countries face trade barriers. Most of these barriers are established on the basis of technical reasons, but the aim is pretty much to protect local producers whose production costs are much higher than those in developing countries. The solution pointed out by some analysts is to liberalize environmental goods and services (EGS) and to include biofuels as EGS. Building up structural international statistics (volumes and prices) on bio-energy trade is desirable, but has not been done so far.

5. Building up long-term sustainable international bio-energy trade

As described above, different issues can hamper the development and growth of international biomass trade flows. On the other hand, it has been shown that further growth is needed to develop working markets and the related industries. To achieve both growing markets and long-term sustainable biomass trade, a pragmatic approach is needed. It is desirable to focus first on routes with low barriers. A compromise should be found between developing certification efforts and ensuring sustainability of bio-energy and developing the market. While not all biomass types may fulfil the entire set of sustainability criteria initially, the emphasis should be on the continuous improvement of sustainability. For such an approach, public information dissemination and support is crucial [Lewandowski and Faaij, 2006].

The main targets and spin-offs of biotrade should lead to a stable and reliable demand for rural communities, provide a source of additional income and an increase in employment for exporting countries, contribute to the sustainable management of natural resources, cost-effectively meet GHG emission reduction targets and diversify the consumer's fuel-mix. Sustainability may best be addressed by a sound certification framework. A gradual process in an international setting seems best to develop this, keeping in mind that a certification process should not become a barrier in itself.

For stakeholders involved such as utilities, producers and suppliers of biomass for energy, it is important to have a clear understanding of the pros and cons of biomass energy. For example, investment in infrastructure and conversion facilities requires risk minimization of supply disruptions, in terms of volume, quality and price. More important even, the long-term future of large-scale international bio-energy trade must rely on environmentally sustainable production of biomass for energy. This requires the development of criteria, project guidelines and a certification system, supported by international bodies. This is particularly relevant for markets that are highly dependent on consumer opinion, as is currently the case in Western Europe. It is even more important for the developing countries and rural regions to be aware of the opportunities and limitations for modern bio-energy in an international setting and to get involved in debate and collaboration for achieving sustainable development where it is most needed. ■

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