BUS-ticket A23[1]

Gerdien Meijerink (LEI), Wolter Elbersen (A&F), Marieke Meeusen (LEI)
Date: November 30, 2004

Bio-fuels in developing countries

1. Introduction
During the 2nd World conference for Biomass and Climate Change in Rome (May 2004) developing countries were considered large potential suppliers of biomass. Unemployment in these often rural areas is high. Developing processing capacity for bio-fuel production at local level in developing countries will contribute to local (non-rural) livelihoods and employment. Bio-fuels were suggested as a serious alternative for (often imported) mineral oil based products. Small-scale schemes converting biomass to bio-fuels might be of interest. The World Bank and the FAO support this approach.

2. Goal
Obtain insight into the criteria for bio-fuels to contribute to local livelihoods
Get insight in the crops suitable for first and second generation bio-fuels[2] (Which plant species are preferred? Small-scale, no competition with the food chain, sustainable, e.g. Jatropha, Cassave)
What would be preferred regions to grow these crops?
How to implement interesting schemes in a sustainable way (focus on people-component)

3. Energy crops

Besides using agricultural, livestock and forestry residues as sources of bio-fuel, there are also specific crops that can be cultivated as “energy crops”. Energy crops can be produced in two main ways: i) as dedicated energy crops on land specifically devoted to this purpose and ii) intercropping with non-energy crops. The way crops are produced has implications for the farming systems (see section on people dimension).

Here we will focus mainly on energy crops for transportation fuels. It is important to distinguish first and second generation bio(transportation)fuels.

The first generation bio-fuels are currently (technically) available. For gasoline motors ethanol is the main option as bio-fuel. Ethanol is currently produced by fermentation from sugars and starch. This means that any starch or sugar containing by-products and crops can be a source. Still, some crops are specifically grown for the purpose of ethanol production. Currently the main crop used for ethanol production is sugar cane, but other crops are also seriously considered. Often both sugar and ethanol are produced in sugar cane mills, because this is more efficient than producing sugar or ethanol separately. An increasing number of third world countries is producing or considering ethanol production specifically for fuel. The prime example is Brazil which has been producing ethanol from sugar cane as a fuel since 1975 (See http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/006/AD430E/AD430E00.HTM for a description of the Brazil ethanol programme)

A number of countries produce or are considering production of ethanol for fuel purposes. Examples are China, Thailand, Argentina, Peru, Mexico, Colombia, South Africa (see annex 2). Motives for ethanol for fuel utilisation are environmental benefits such as prevention of air pollution (smog, lead, etc), less dependency on oil imports and support of farmers. In table 1

[1] Copying of (part of) this report is allowed only with proper citation. This report aims to provide a quick scan of the subject matter and should therefore be used as such. The contents do not represent the official view of the BUS nor of any of its affiliates, but are personal to the writer. The BUS accepts no liability for the use of this information nor for any consequences that may result from it.
[2] First generation: ethanol from starch and sugar, and fatty acid methyl esters. Second generation: lignocellulose biomass

an overview is given of the world ethanol production and outlook for 2010. Table 2 shows which third world countries are expected to make a contribution to ethanol production.

Table 1. World ethanol production in tonnes x 1000.

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**18 391**	**19 418**	**19 284**	**25 192**	**26 768**	**0.4**	**3**
Brazil	12 028	12 700	10 900	14 268	14 017	-0.9	2.3
OECD Countries Total	3 487	3 789	5 129	7 214	8 790	3.6	5
United States	2 216	2 540	3 999	5 905	7 359	5.5	5.7
EU 15	1 144	1 121	1 002	1 174	1 293	-1.2	2.3
Mexico	126	128	128	135	137	0.1	0.7
India	1 175	1 434	1 985	2 290	2 434	4.9	1.9
China, Mainland	43	125	200	212	220	15.1	0.9
ACP Countries	14	18	21	24	26	3.8	1.8
Thailand	77	86	90	94	97	1.4	0.7
Former USSR	191	393	263	286	302	2.9	1.3
Rest of World	1 377	873	697	803	881	-6	2.2

Source: FAOSTAT (1990,1995,2000)

In annex 2 a discussion is given of recent developments in third world countries.

Table 2. The most important ethanol crops in the developing world

Crop	**Where?**	**Yields?**	**Remarks**
Sugar cane	All tropical and sub-tropical areas. Brazil is largest producer	Up to 4500 litre ethanol/ha/year	C4 grass, sugar crop. By far the most important crop
Cassava/ Tapioca	All tropical areas. Thailand is largest producer of ethanol from tapioca.	Up to 6700 litre ethanol/ha/year	Tuber starch crop. Adapted to low fertile soils.
Sweet sorghum	Also suited for milder climates (China, southen Europe?)	Up to 6500 litre ethanol /ha/year	C4 grass, sugar crop, will grow in temperate areas where sugar cane is not an option.
Grain crops (corn, wheat, etc)	China, Thailand		These are not specific energy crops.

See http://www.praj.net/article2.htm and other sources.

For diesel motors the main options are fatty acid methyl esters or pure plant oil (the first diesel motor ran on pure peanut oil). This means that in principle any oil can be used, though quality factors such as clouding point determine suitability. In annex 3 a list of oil crops is given. It appears that contrary to ethanol many different crops are considered. It is interesting to note that the highest yielding crops are all tree crops such as Palm oil, Jatropha and Castor bean. It seems that due to smaller scale and cheaper processing options oil crops for biodiesel may be easier to implement in poorer developing countries.

Second generation bio-fuels are mainly based on lignocellulose biomass from which a much wider range of fuels can be produced to replace diesel, gasoline or completely new systems like fuel cells
The most important second generation bio-fuels are lignocellulosic ethanol and Fisher Tropsch biodiesel. Still other fuels like methanol, buthanol, pyrolysis oil and biogas and in the future also hydrogen may be considered.

As feedstocks most agricultural by-products and residues can be used. Specific crops for second generation biofuels will generally be lignocellose crops. Dedicated crops suitable for second generation bio-fuel are therefore any crop that can produce large quantities of biomass at low cost that are easy to handle and process. They should have low input/output ratios. Overall cropping systems should have:

- High water use efficiency (kg water per kg DM)
- Low fertiliser use
- Low pesticide use
- Low labour use
- Low machinery use
- Low soil requirements
- High yields per ha

The demands mentioned above will generally exclude rotation crops as these require yearly planting or seeding and related inputs. As in Europe and North America, crops for second generation fuels will be perennial lignocellulosic crops such as C4 grasses and trees. Compared to C3 crops C4 grasses have a more efficient photosynthesis system allowing to utilise sun light more efficiently and use water more efficiently. Additional advantages are the lower ash content, because as ash content is related to water use and a lower (N) nutrient requirement.

Some crops that have been specifically mentioned for linocellulosic biomass production in developing countries are: Vetiver grass (C4), Miscanthus (C4), Arundo donax (C4), Switchgrass (C4), Bamboo (C4), Eucalyptus (Tree).

4. Technologies

During the last decade a wide range of technologies and expertise has been developed to convert biomass into heat, electricity and bio-fuels (Sims, 2002). Each type of conversion technology has its specific characteristics that impose certain restrictions on the biomass. The main requirements concern moisture content, degree of pollution/ash content, chemical composition, structure and shape and required pre-treatments. This means that there is a direct link between the technology used to convert biomass into bio-fuel and the production of biomass by farmers. This has implications for farming systems, as we will discuss in following sections.

For developing countries, large scale power plants are often not feasible due to the large investment costs, and required capacity in terms of supply of biomass, transport, infrastructure etc which is often not available in (poor) countries. Of the biomass conversion technologies, combustion is more suitable for large scale power plants than gasification (Annevelink et al., 2004).

Small scale power plants would suit many developing countries. However, gasification, which could be an option for small scale power plants, still needs a lot of technical effort to achieve a somewhat higher energy efficiency and the operation of a gasification installation requires certain skills (Annevelink et al., 2004).

Ethanol and second generation energy crops and conversion chains require sophisticated technology and investment making them generally unavailable for poorer developing world countries. As is already the case, more developed countries with large agricultural potential such as Brazil, Malaysia and Thailand are the countries implementing ethanol and second generation transportation fuels.

Oleiferous crops are relatively easy to grow, process and distribute and may therefore be suited to poorer developing countries.

5. A checklist for assessing the sustainability of biomass for energy

The role of biomass for energy purposes
The WEC (2005) states that it is difficult to predict at this stage what will be the future role of biomass specifically grown for energy purposes. This is, in many ways, a new concept for the farmer and we will discuss a few issues in the next sections. If large-scale energy crops are to form an integral part of farming practices, it will have several implications for farming systems.

In the past decade a large number of studies has aimed to estimate the global potential for energy from future energy forestry/crop plantations (WEC, 2005). These range from about 100 million ha to over a billion ha, e.g. Hall et al (1993) estimated that as much as 267 EJ/yr could be produced from biomass plantations alone, requiring about one billion hectares. However, it is highly unlikely that such forestry/crops would be used on such a large scale, owing to a combination of factors, such as land availability, possible fuel versus food conflict, potential climatic factors, higher investment cost of degraded land, land rights, etc. The most likely scenario would be at the lower end of the scale, e.g. 100-300 million ha.

The agricultural and technological possibilities for bio-fuel production in developing countries often do exist. However, the implementation of technological solutions in these countries are usually obstructed by different socio-economic factors, that reflect general conditions in many developing regions, for example, complex or disputed land ownership, lack of roads or other means to transport biomass to processing facilities and bio-fuels to markets (Larson & Williams, 1995). Despite these technical, socio-economic, political, and other difficulties, however, proof of the potential for growing energy crops on degraded lands can be found in the many successful energy plantations that already exist in developing countries.

A framework for a sustainable production of biomass for energy purposes
When a (new energy) crop is introduced into a farming system that can be used as a bio-fuel, there will be several implications that need to be taken into account to ensure that the energy crop will contribute to sustainable local livelihoods and not (unintentionally) leads to negative effects.

According to the FAO, a livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living; a livelihood is sustainable when it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and when it contributes net benefits to other livelihoods at the local and global levels in the short and long term (Hardaker, 1997). We put sustainable livelihoods in the context of sustainable agriculture.

Sustainable agriculture fulfills the following criteria (Hardaker, 1997):

- Meeting the basic nutritional requirements of present and future generations, qualitatively and quantitatively, while providing a number of other agricultural products.
- Providing durable employment, sufficient income, and decent living and working conditions for all those engaged in agricultural production.

- Maintaining and, where possible, enhancing the productive capacity of the natural resource base as a whole, and the regenerative capacity of renewable resources, without disrupting the functioning of basic ecological cycles and natural balances, destroying the socio-cultural attributes of rural communities, or causing contamination of the environment.
- Reducing the vulnerability of the agricultural sector to adverse natural and socio-economic factors and other risks, and strengthening self-reliance.

We will address these issues under the following headings:

- Issues concerning the use of inputs
- Issues concerning the processing, transport and marketing of outputs

These issues will be assessed in the next paragraphs.

6. Use of inputs

Resources in developing countries are in general scarce. Introduction of a new crop is often at the expense of other crops, because of stringent land, labour or cash constraints. The effects of substitution are all locally specific, because of the type of substituted crop, type of substituted land/area are locally specific.

However, if it concerns an existing crop which has a new application, it may result in creation and opening up of new markets for farmers – e.g. for sugarcane or maize farmers (from which ethanol can be produced).

Land

Land is one of the most important inputs in agriculture. It encompasses two dimensions: quantity (amount of land, or area) and quality (soil fertility). Land of good quality (high fertility) is often a scarce resource, and the most important crops (often the most profitable) are usually cultivated on good quality lands. Because the area around the homestead usually received most (organic) fertilizer such as manure[3], this area is also frequently the most fertile. Crops that are more extensive are usually cultivated on land that is further away.

To minimise competition between agriculture and energy production, a number of analysts have proposed that developing countries target degraded lands for energy production (Johansson et al., 1994). Grainger (1988) and Oldeman et al. (1991) have estimated that developing countries have over 2,000 million hectares of degraded lands, and Grainger estimates that some 621 million of these are suitable for reforestation. This is consistent with estimates that previously forested area suitable for reforestation amounts to 500 million hectares, with an additional 365 million hectares available from land in the fallow phase of shifting cultivation. However, large-scale harvesting of biomass will lead to nutrient depletion and if not replenished will lead to greater degradation of land.

Fertilisers

If substantial amounts of biomass are harvested, this will lead to nutrient depletion of the soils, which needs to be replenished by (in)organic fertilizers. This involves an additional investment if the farmer does not want to deplete the soil. In many poor countries, fertilizers are too expensive to be profitable. It therefore depends on the relationship between output prices (for bio-fuels) and input prices (fertilizer) whether use of fertilizer is feasible In many poor countries the infrastructure and institutions to deliver inputs (seeds, fertilizers etc) are not there.

If nutrients are not replaced, growing bio-fuel crops can lead to extensive nutrient depletion, which has been shown to result in (severe) erosion.

[3] This is due to transport constraints of manure to fields that are far away

Water
Water may be another restrictive factor, if the bio-fuel crop is a water-intensive crop. In many poor countries investments in water pumps or other technical means to obtain water are not feasible due to lack of funds.

Labour
Labour is another important input factor. Although in many rural areas, there is (hidden) unemployment, labour can be restrictive factor during peak, harvesting days. Poor rural households are not always able to hire labour due to financial reasons. The distinction between male and female labour is also important when assessing labour availability. Some work is done by men and other by women – they are not always substitutable.

Labour is used for growing the crop – from preparing land to harvesting. But labour is also used for post-harvest activities such as storage and processing. The amount of labour available for these activities is important, but also the necessary skills. Does the bio-fuel crop require special skills for cultivation, storage or processing?

Residues
It is often claimed that residues of crops can be used for bio-fuels. However, in many developing countries these residues are already used for a number of purposes, such as livestock fodder, green manure (i.e. organic fertiliser), food (such as cassava leaves). Resources are scarce in most developing countries and there are often no residues that are simply discarded. Most residues have a function in the farming system.

Other investments
The last issue to consider are other investments not covered above, such as necessary tools to harvest bio-fuel crops, or processing facilities. If additional investments are needed, this may pose additional constraints to (poor) farmers.

7. Processing, marketing and transporting outputs
The example of bio-fuel (sugarcane) in Brazil (see annex) teaches us that how and where the biomass is processed has important implications. Goldemberg and Johansson (1995) argue that most discussions of the energy sector have focussed on supply-side issues only, but that the whole chain is important from collection and extraction of primary energy, which is converted into energy carriers suitable for the end-use. Thus, production of bio-fuels cannot be analysed in isolation of processing. However, processing of bio-fuels may signify agribusiness opportunities for the region, if necessary capacity (in terms of skills, investments, infrastructure etc) is available.

In Africa agro-industrial enterprises are relatively rare, while in Asia and Latin America there is a much longer tradition of processing agricultural products (Vellema, 2004). For Africa, the opportunities for producing large-scale bio-fuel will therefore be limited.

With respect to the type of output, it is important to consider which product of a crop is used for bio-fuel. Is the whole crop harvested or are only by-products harvested? In the latter case, are the remaining parts of the crop useful to the household, or can they be sold as well? In this case, additional income can increase the profitability of the bio-fuel.

With respect to marketing and transport of the output it is important to consider what is marketed in what form and to whom. The infrastructure and institutions for marketing are often incomplete in many (poor) developing countries. Is the necessary infrastructure (roads, vehicles) present to transport the bio-fuel products from the farm to processing plants or major markets (i.e. regional capitals or ports)? Are well-functioning institutions present (i.e. a marketing chain, information, contracts etc) to ensure that producers can sell their bio-fuel produce? In general, energy conversion (industrial) units must have a minimum size to achieve a reasonable efficiency, which means that there must be a minimum supply from producers. This means that growing bio-fuel crops is only feasible if a (large) group of farmers can organise themselves to grow a sufficient amount of biomass. The experience in Brazil (see annex) also shows that transportation costs set an upper limit to how much biomass is efficiently available.

8. Conclusions

Suitable energycrops

- First generation ethanol and second generation energy crops and conversion chains require relatively large systems and often sophisticated technology and large investments which are generally unavailable for poorer developing world countries. As is already the case more developed countries with large agricultural potentials such as Brazil, China and Thailand are or will be the countries implementing first generation ethanol and second generation transportation fuels.
- Oleiferous crops are relatively easy to grow, process and distribute and may therefore be suited to the conditions in poorer developing countries. An alternative for these countries is to export the raw (or half-processed) biomass if a (stable) and high price can be obtained.
- The number of crops considered for ethanol production seems limited to sugar cane, sweet sorgum, cassava, (sugarbeet), and existing grains crops. The options for oil producing crops appear to be much wider perhaps reflecting the smaller scale nature of the production system.
- For second generation bio-fuels (based on lignocellulose biomass) no specific crops have really been developed. One can expect that apart from by-products perennial low input highly productive C4 grasses and trees will be used.

Producing biomass in a sustainable way with respect to the people-component

- Growing energy crops instead of crops that are meant for the domestic (family) food supply is not recommended. It is important to see energy crops as a *cash* crop.
- Growing energy crops (i.e. biomass) for bio-fuels is only an interesting option to developing countries when these crops are more profitable than existing (cash) crops, because there is already competition between scarce resources such as land, fertilizer water and labour. Especially (soil) nutrients are an important consideration. Farmers will adopt energy crops when these are more profitable than other (cash) crops. For instance, cocoa and coffee crops that have been planted by many small-scale farmers (notably in Latin America, West Africa, parts of East Africa and some parts of Asia) have in many cases ceased to be profitable because of the low cocoa and coffee prices. These small-scale “plantations” may be replaced by more profitable energy crops.
- Growing energy crops instead of cash crops that are used as food for the developing countries is not recommended. One of the reasons that opposes growing energy crops that is often cited is that it will jeopardize food security in these countries. At a *macro*-level this may be an important consideration. When farmers switch from growing food crops to energy crops, food prices may rise. However, this will probably not affect farmers in developing countries, as they will always grow their own food crops on part of their land (often by the women). They will not likely replace these food crops as farm households will usually spread risk and will safeguard their food production. Higher food prices may, however, affect landless and urban poor.

Therefore, growing energy crops is only sustainable from a “people point of view” when it replaces (a) cash crops (b) with a lower profit and (c) which are not used as food for the developing countries.

Processing, marketing and transporting outputs
Developing processing capacity at local level in developing countries will contribute to local (non-rural) livelihoods and employment. The value added will remain in the country and will increase the benefits of bio-energy. However, in many poor countries (especially in Sub-Saharan Africa), the capacity (infrastructure, capital etc) for establishing processing industry is not available. Developing this capacity may need to be part of introducing bio-fuel crops.

References

- Beld, B. van der, 2004. Interview on the role of BTG concerning technology transfer with the emphasis on pyrolysis, 26 April. Cited in: *Annevelink, B., G.J. Nabuurs & W. Elbersen. 2004 Case study on the potential for induced technological spillovers in a specific carbon neutral energy supply industry: biomass and bio-energy chains. Climate Change and Biosphere Research Centre (CCB) Wageningen UR*
- Grainger, A. 1988. Estimating Areas of Degraded Tropical Lands Requiring Replenishment of Forest Cover. International Tree Crops Journal, Vol. 5 (1988), pp. 31-61.
- Hall, D.O., Rosillo-Calle, F., Williams, R.H. & Woods, J. (1993) Biomass for Energy: Supply Prospects. Chapter 14 in Renewables for Fuels and Electricity, ed. B.J. Johansson, et al, Island Press, Washington, DC;
- Hardaker, J.B. 1997 Guidelines for the integration of sustainable agriculture and rural development into agricultural policies. (FAO agricultural policy and economic development series 4). FAO: Rome.
- Houghton, R.A. 1990. The Future Role of Tropical Forests in Affecting the Carbon Dioxide Concentration of the Atmosphere. Ambio 19(4) (1990), pp. 204-09.
- J. Goldemberg and T.B. Johansson, (Editors). 1995. Energy As An Instrument for Socio-Economic Development. United Nations Development Programme, New York, NY.
- Johansson, T., H. Kelly, A.K.N. Reddy, and R.H. Williams. 1993 "Renewable Fuels and Electricity for a Growing World Economy: Defining and Achieving the Potential," Chapter 1, pp. 1-71, in: T.B. Johansson et al. (eds.). 1993. Renewable Energy. Island Press: Washington, DC.
- Larson, E. & R. Williams, Biomass Plantation Energy Systems and Sustainable Development. 1995. In: J. Goldemberg and T.B. Johansson, (Editors). 1995. Energy As An Instrument for Socio-Economic Development. United Nations Development Programme, New York, NY.
- Oldeman, L.R. et al., 1991. World Map of the Status of Human Induced Soil Degradation, International Soil Reference and Information Center and United Nations Environment Programme.
- Sims, R.E.H., 2002. The brilliance of bioenergy in business and in practice. James & James, London. UK, 316 pp.
- WEC (World Energy Council) 2005. Survey of energy resources: Biomass (other than wood). Available at: www.worldenergy.org
- Den Uil et al., 2003. Conventional bio-transportation fuels. An Update. ECN, ATO.
- Thomas, V, and A. Kwong, 2001. Ethanol as a lead replacement: phasing out leaded gasoline in Africa. Energy Policy 29 (2001) 1133–1143.

Annex 1: example

Converting Biomass to Liquid Fuels: Making Ethanol from Sugar Cane in Brazil
Isaias de Carvalho Macedo

In: J. Goldemberg and T.B. Johansson, (Editors). 1995. Energy As An Instrument for Socio-Economic Development. United Nations Development Programme, New York, NY,

One of the largest commercial efforts to convert biomass to energy anywhere in the world today is the substitution of sugar- cane-based ethanol for gasoline in passenger cars in Brazil.

Fuel for cars and light vehicles in Brazil is either neat-ethanol (94 per cent ethanol, 6 per cent water) or gasohol (78 per cent gasoline, 22 per cent ethanol). The programme to promote ethanol production was established in 1975 to reduce the country's dependence on imported oil, and to help stabilize sugar production in the context of cyclical international prices; it includes government-sponsored incentives to promote private production. By 1989, production reached 12 million cubic metres annually and continues at that level.

Important issues:

the programme is almost entirely based on locally manufactured equipment, helping to establish a strong agro-industrial system, with a significant number of indirect jobs.

The size of any biomass-based energy production system is determined by at least two factors:

1. the energy conversion (industrial) unit must have a minimum size to achieve a reasonable efficiency,
2. but transportation costs set an upper limit to how much biomass is efficiently available. This is very important for wood-to-electricity systems (leading to development of wood gasifiers and gas turbines), for higher efficiencies at low power levels); and it is also true for sugar cane to ethanol systems.

Thus, the so-called large-scale ethanol production system in Brazil is actually composed of a large number (approximately 400) of industrial units, with cane production areas in the range of 5,000 to 50,000 hectares. This much smaller-scale system is further decentralized by the fact that sugar cane is produced by more than 60,000 suppliers. External suppliers produced approximately 38 percent of the sugar processed in 1986, with mill owners themselves providing approximately 62 percent.

The seasonality of sugar cane production has a big impact on its ability to create high quality jobs. Climatic conditions and agronomic characteristics of the crop limit the harvesting season to six months out of the year in Brazil. The amount of manpower needed during the harvesting and the off season is largely determined by the level of agricultural technology employed. Because the work associated with sugar cane production is highly seasonal, jobs tend to be temporary; this, in turn, leads to high turnover, difficulty in training and, consequently, low wages.

Sugar and ethanol production have in common the costs of sugar cane production, delivery to the mill, cane preparation, milling, and utilities.

Annex 2

Latest information on ethanol production and usage in developing world countries from the **WORLD FUEL ETHANOL: ANALYSIS AND OUTLOOK**. By Dr. Christoph Berg April 2004. http://www.distill.com/World-Fuel-Ethanol-A&O-2004.html

India
India's transport sector is growing rapidly and presently accounts for over half of the country's oil consumption whilst the country has to import a large part of its oil needs. Hastening interest in an ethanol program was the country's sugar glut (part of which the industry is now exporting to the world market) and burgeoning supplies of molasses. The sugar industry lobbied the government to embrace a bio-ethanol programme for several years. The industry emphasised that producing fuel ethanol would absorb the sugar surplus and help the country's distillery sector, which is presently burdened with huge overcapacity, and also allow value adding to by-products, particularly molasses.

India's Minister for Petroleum and Natural Gas gave his approval in December 2001 to a proposal to launch pilot projects to test the feasibility of blending ethanol with gasoline. Mid-March 2002 the government decided to allow the sale of E-5 across the country. On 13 September, 2002, India's government mandated that nine states and four federally ruled areas will have to sell E-5 by law from 1 January 2003. In response India's sugar producers reportedly planned to build 20 ethanol plants before the end of the year in addition to 10 plants already constructed. Most of the plants were being constructed in Uttar Pradesh, Maharashtra and Tamil Nadu, the key sugar producing states and will chiefly use cane sugar molasses as a feedstock.

Estimated annual ethanol needs for a E-5 blend is 0.37 bln litres. A 10% blend increases the need to 0.72 bln litres. This is against installed annual production capacity of 2.7 bln litres/year and annual consumption of 1.5 bln litres. These figures have to be treated with some caution. The chemical industry, fearing higher ethanol prices as a result of the fuel alcohol programme, usually estimates the surplus to be much lower or even non-existent. The sugar industry, on the other hand, estimates capacity at 3.2 bln litres inflating the surplus.

The success of ethanol in India will depend to a significant degree on pricing. The sugar industry originally claimed that it could provide ethanol at 19 Rupees per litre ($0.38/litre), which is at a lower cost than the product it would substitute, MTBE, which costs 24-26 rupees per litre ($0.49-0.53/litre). The oil industry however is seeking parity between ethanol and the price of gasoline on an ex-refinery or import basis. In April 2002 the government announced a Rs0.75 excise duty exemption. Implementation of the excise duty for ethanol which, however, was delayed however until February 2003, because the chemical industry opposed it, fearing higher prices and shortages of alcohol.

However, pricing appears to becoming a stumbling block and in June 2003 India's Petroleum Ministry announced that it would appoint a Tariff Commission to fix an appropriate price for ethanol sourced from sugar mills. Ethanol pricing in India is also complicated by differences in excise duty and sales tax across states and the central government is trying to rationalize ethanol sales tax across the country. More significantly perhaps, there are still substantial differences in the profitability of potable alcohol as against fuel alcohol and in several states. Consequently, insufficient fuel alcohol is being produced to meet demand. Other states have yet to set up sufficient production capacity. Analysts expect that there is a deficit of around 150 mln litres under the current geographic base to the fuel ethanol program; a deficit that will grow once the mandated blending requirement is extended to all states in India. Consequently, there may be a short-term market for imported Brazilian ethanol.

Thailand
Thailand's interest in establishing a large-scale bio-ethanol industry using feedstock such as cassava, sugar cane and rice, was manifested in September 2000, and reflects the nation's rising import bill for oil (the country is 90% reliant on imports) and high-energy prices which were adversely impacting the economy at that time. At the same time low prices for commodities such as sugar and cassava were a matter of concern for the government.

The Thai government moved swiftly in supporting the ethanol opportunity with the oil import bill as the swaying reason for pursuing the bio-ethanol programme. More recently, the role of ethanol in replacing MTBE has been offered as another justification for the ethanol program. The National Ethanol Development Committee has estimated that if 10% ethanol were blended with petrol or diesel, to replace MTBE, about 2 mln litres of ethanol would be required on a daily basis.

In order to encourage manufacturers to develop and market gasohol the Finance Ministry will waive the excise tax on gasohol as well as contributions to the State Oil Fund and Energy Conservation Fund. Furthermore to encourage investment in new capacity, promotion privileges are to be given by the Board of Investment. Tax privileges will be granted including duty exemptions on machinery imports and an eight-year corporate tax holiday. The Industry Ministry calculates the gasoline/ethanol blend would be 0.7-1.0 Baht/litre (US$0.01-0.02/litre) cheaper than conventional gasoline.

Late in 2001, eight private companies were granted licences by Thailand's Ministry of Industry to build ethanol production plants. The plants had a capacity to produce 1.5 mln litres of ethanol a day, or an annual capacity of around 0.495 bln litres. Four plants would use molasses as a feedstock and the others would use cavassa (tapioca). Five of the plants were expected to start production late in 2002 with a combined annual output of 114 mln litres. However, progress in constructing the plants has faltered. By mid 2003, only one distillery had advanced to construction stage and many had not submitted feasibility plans.

China
China is now home to the world's largest fuel ethanol plant. The Jilin Tianhe Ethanol Distillery has an initial capacity of 600,000 tonnes a year or 2.5 mln litres per day. Potential final capacity can be raised to 800,000 tonnes per year. Ground breaking took place in September 2001 and by late 2003 the first trials had started.

In November 2002 construction on a plant designed to produce 300,000 tonnes of fuel ethanol annually started in Nanyang, Henan province. The project, built by the Tianguan Ethanol Chemical Group Co., Ltd. (TICG), is expected to cost $155 mln and take two years to complete. Combined with the company's existing facility, TICG's total fuel ethanol capacity would reach 500,000 tonnes a year.

Fuel ethanol has already been in trial use in China for some time. From 2001, Zhengzhou, Luoyang and Nanyang in Henan as well as Harbin and Zhaodong in Heilongjiang province have been experimenting with using ethanol as a vehicle fuel. China is promoting ethanol-based fuel on a pilot basis in five cities in its central and north-eastern regions, a move designed to create a new market for its surplus grain and to reduce oil consumption. The promotion of ethanol as a fuel has been approved by the State Planning and Trade Commission and the State Development and Planning Commission.

Peru and other Latin America
In summer 2002, the Peruvian government announced that the country plans to become a leading ethanol exporter. Under the so-called Mega-project the country plans to construct a pipeline from the central jungle in the north of Peru to the port of Bajovar. Under the project

up to 20 distilleries will be built which all plan to use sugar cane juice as a raw material. The overall investment costs are estimated at around $200 mln.

Peru is planning that by December 2004 it will begin exporting the first lots of ethanol to California. Under the first stage of the project, some 100 mln litres will be exported by 2005, rising to 1.2 bln by 2010. In order to sustain the project, the country plans to introduce up to 240,000 ha of sugar cane in jungle areas, now home to the production of much of Peru's coca leaf. This is used to make cocaine of which Peru is the world's second biggest producer. The government hopes that coca farmers will see that sugar cane growing is a much more profitable enterprise.

In September 2001, the Colombian government approved a law which will make mandatory from 2006 the use of 10% ethanol in fuel in cities with populations larger than 500,000 inhabitants. According to the Ministry of Agriculture, this program will require the cultivation of an additional 150,000 ha of sugar cane. This compares with the present area under cane for sugar production of around 200,000 ha. Another 230,000 ha under cane are used for the production of non-centrifugal sugar, in Colombia's case panela. In order to supply the domestic market nine new ethanol plants have to be built from scratch in order to achieve the required production capacity of around 1 bln litres a year. In order to attract sufficient investment, the country will completely exempt ethanol from the tax on gasoline which would result in a significant price advantage of the green fuel. At present it may not be gauged whether or not the investment drive in Colombia will result in any surplus capacity.

The Association of Central American Countries is also looking at the possibility to increasingly produce fuel alcohol. Total output by 2010 is expected to reach around 500 mln litres, which would allow for a 10% ethanol blend in gasoline. However, the association is also looking at diversifying its export markets. At the moment, Costa Rica, Jamaica and El Salvador are exporting fuel ethanol to the United States under the Caribbean Basin Economic Recovery Act. Under this scheme the countries mentioned may import raw alcohol and re-export it duty-free to the United States.

Latin America is likely to continue to lead the world in fuel ethanol production. This may be explained with the high yields in sugar cane production and the fact that many of these economies are agriculturally based. Several projects in Latin America such as Peru, Colombia or the Central American states were already mentioned. We may see large trade flows from South America to North America in general and California in particular. Another trade flow may be directed at the Asian/Pacific region and here Japan and possibly South Korea could take a top position. Moreover, there is the possibility of a developing export flow from South America to the European Union. As has been mentioned earlier, the European Union could develop into a net importing country if the Commission's directives are implemented. Several countries in Latin America enjoy duty-fee access to the European market and they would be in a prime position to act as suppliers. A third trade flow in the Americas will consist of raw alcohol from Brazil to the Caribbean and onwards to the United States. This sort of trade is likely to continue as long as Brazil does not enjoy duty free access to the US under the Free Trade Area of the Americas.

Southern Africa
Southern Africa is another potential supplier to the world market also because of relatively high sugar cane yields and some under-utilized areas. Several South African countries also enjoy duty-free access to the European Union and therefore, some quantities may go there. Another potential export market for distillers in sub-Saharan Africa could be the Far East. In Asia, India, Thailand and Australia may emerge as smaller to medium sized exporters with South Korea and Japan on the importing side.

Annex 3.

List of oil crops and oil yields (these yields are for a good crop)

Crop	kg oil/ha	litres oil/ha	Crop type
corn (maize)	145	172	Annual crop
cashew nut	148	176	
oats	183	217	Annual crop
lupine	195	232	Annual crop
kenaf	230	273	Annual crop
calendula	256	305	
cotton	273	325	Annual crop
hemp	305	363	Annual crop
soybean	375	446	Annual crop
coffee	386	459	
linseed (flax)	402	478	Annual crop
hazelnuts	405	482	Tree
euphorbia	440	524	
pumpkin seed	449	534	
coriander	450	536	Annual crop
mustard seed	481	572	Annual crop
camelina	490	583	
sesame	585	696	Annual crop
safflower	655	779	Annual crop
rice	696	828	Annual crop
tung oil tree	790	940	Tree
sunflowers	800	952	Annual crop
cocoa (cacao)	863	1026	Tree
peanuts	890	1059	Annual crop
opium poppy	978	1163	Annual crop
rapeseed	1000	1190	Annual crop
olives	1019	1212	Tree
castor beans	1188	1413	Tree
pecan nuts	1505	1791	Tree
jojoba	1528	1818	shrub
jatropha	1590	1892	Tree
macadamia nuts	1887	2246	Tree
brazil nuts	2010	2392	Tree
avocado	2217	2638	Tree
coconut	2260	2689	Tree
oil palm	5000	5950	Tree