BIOENERGY AND AGROFUELS
Relevance beyond polemics

Albert SASSON

Publication supported by the Hassan II Academy of Science and Technology
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PREFACE

The Hassan II Academy of Science and Technology has been created by a Royal Decree on October 6, 1993 and enjoys the protection and tutorship of His Majesty the King of Morocco, Mohammed VI. The Academy's missions are to promote scientific and technological research particularly through assessing, supporting and funding research programmes and projects; to issue recommendations on the national science and technology policy and priorities; and to contribute to the dissemination of scientific culture and progress.

In addition to the Proceedings of its sessions, and in particular of its annual plenary session devoted to a specific theme of worldwide relevance, the Academy publishes a Bulletin and a Newsletter. It also promotes and supports the publications and reports dealing with subjects of interest to its scientific colleges. This publication, authored by Professor Albert Sasson, a founding member of the Academy, provides the state-of-knowledge on the relevance on *Agrofuels* as a source of energy.

The Academy is very glad to support the publication of this report by one of its distinguished members who enjoys a long-standing reputation for disseminating scientific and technological knowledge, especially with respect to biotechnology in developing countries over the last 35 years.

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CONTENTS

FOREWORD

Most of global energy consumption is currently met by fossil fuels, particularly oil. Rapid growth in oil demand, finite oil supplies (although discovery of new deposits of oil is continuing, but their access and exploitation are becoming increasingly difficult) and political instability in many of the major oil-exporting countries are pushing up oil prices and making them more volatile. This trend seems to be durable.

Most countries (including oil-exporting ones) are therefore trying to save energy and to diversify their energy sources, particularly sources of renewable energy (wind, solar, hydroelectric power, sea-powered turbines). They are looking at bioenergy as a potentially attractive prospect. Nowadays, roughly 10% of humankind's energy comes from biomass. Whereas oil and coal are unevenly distributed among countries, all of them can generate some bioenergy from domestically produced biomass of one type or another. Most biomass in industrial countries is converted into electricity and heat in plants, whereas in developing countries it is mostly burnt by rural households for cooking and heating.

There are two main types of agrofuels: bioethanol and biodiesel. Bioethanol can be obtained through fermentation by yeasts of feedstocks rich in sucrose (e.g. sugar-cane juice, molasses and sweet sorghum), materials rich in starch (e.g. maize, wheat, barley or cassava) and cellulose-rich materials (cellulose being hydrolyzed into fermentable sugars), e.g. forestry and agricultural residues or wastes, and grassy species. So far, bioethanol is commercially produced from the first two kinds of feedstocks, although intensive research is being carried out to produce bioethanol from cellulose and hemicellulose (xylans). Bioethanol can be used as fuel to replace gasoline, but this requires specially adapted engines; generally, it is blended with gasoline (10% to 25%).

Biodiesel is derived from the esterification of vegetable oils (e.g. palm, rapeseed, soybean, and castor bean oils) or animal fats or used frying oil, in order to be blended with hydrocarbon diesel (e.g. 30% in B30 diesel).

Both liquid agrofuels are used for transport and are still relatively minor sources of energy. In 2007, world production of bioethanol amounted to 55.7 billion liters (4% of world consumption of gasoline). The United States was the leading producer (48%), followed by Brazil (31%), which was the world's biggest exporter (Gasnier, 2008b). While in Brazil bioethanol has displaced over 40% of gasoline use, the percentage is only 3% in the United States. In 2006-2007, global diesel production was only about one-tenth of total ethanol production, and the European Union, especially Germany and France, was the largest producer of biodiesel (88% of world production).

Although agrofuels currently contribute to a small fraction of the energy consumed in transport, they are considered by many countries as a means to decrease their dependence on oil and to improve their energy security. And indeed plantations of energy crops, refineries and a whole industry are expanding worldwide; heavy investments are being made and industrial conglomerates backed by funds and financial mechanisms are being consolidated.

Agrofuels have not been spared by polemics around the following questions: are they improving the energy equation? Is their consumption reducing carbon dioxide emissions compared with oil and oil-derived fuels? Is their production displacing forest land and natural ecosystems, thereby generating additional emissions of greenhouse gases? And finally are they replacing food crops and thus becoming a threat to food supply?

Beyond the polemics, and while acknowledging that agriculture must continue to meet the food needs of the world in the most efficient way and to be considered a high priority on national and international agendas and aid programmes, it can contribute to meeting the world's needs in agrofuels and biomaterials. The situation should be reviewed country by country, and without overstating the role of agrofuels in the overall energy economy and balance, reasonable targets of production in those countries that choose the most appropriate energy crop species and bioengineering process, can contribute to the diversification of energy sources, particularly in transport, without harming food production and farmers' income.

GLOBAL ENERGY CONSUMPTION AND GROWTH

Total global energy consumption is huge - about 400 EJ (exajoules) per year - and is expected to grow 50% by 2025. Most of that increase will occur in developing countries, especially China and India. Most of this demand is currently met by fossil fuels, particularly oil. Rapid growth in oil demand, finite oil supplies and political instability in many of the major oil-exporting countries are pushing up oil prices and making them more volatile. There is therefore a need to save energy and to diversify its sources, bioenergy being a potentially attractive prospect (Hazell and Pachauri, 2006).

The energy equation and mitigating climate change

Energy consumption must be reduced, and many experts consider that the largest deposit of energy lies in the decrease of its consumption. But there is no point to request the car companies to make their cars more energy-efficient, if the number of cars continues to grow and if public policies continue to be geared towards making this happen. On the other hand, the car industry provides employment and the improvement in the standard of living leads people to buy cars and gain in autonomy. The entire economic system has to be reviewed in order to meet what may seem contradictory needs. However, it is necessary to reduce the waste of energy drastically.

In the case of agriculture, the Food and Agriculture Organization of the United Nations (FAO) calculated that, on average, farmers in industrialized countries spent five times as much commercial energy to produce one kilogram of cereal as did farmers in Africa. To produce 1 kg of maize, a US farmer uses 33 times as much commercial energy as his or her traditional neighbour from Mexico; and to produce 1 kg of rice, a farmer in the United States uses 80 times the commercial energy used by a traditional farmer in the Philippines. This commercial energy is mostly the fossil-fuel oil and gas needed for the manufacture of fertilizers and agrochemicals, and used by farm machinery, all of which substantially contribute to the emission of greenhouse-effect gases (*Seedling*, July 2007, pp. 2-7). On the other hand, increasing the reasonable use of fertilizers by African farmers (the lowest in the world) will increase yields and improve nutritional conditions in countries where starvation and malnutrition is widespread. Malawi is a striking example in this respect: in 2005, after a serious drought, Malawi's president launched a US$60-million programme to supply low-cost fertilizers to farmers; three years later, yields trebled and Malawi became an exporter of cereals in the region. It should be underlined that this policy was contrary to the donors' advice, including the World Bank, which have been trying to convince Malawi's government to eliminate subsidies, in particular to fertilizers.

But then, agriculture consumes only about a quarter of the energy used to bring food to our tables. The real waste occurs in the processing, packaging, freezing, cooking and moving of food around the globe. For instance, every day 3,500 pigs travel from different European countries to Spain, while on the same day 3,000 other pigs travel in the opposite direction. Spain imports 220,000 kg of potatoes every day from the United Kingdom, while it exports 72,000 kg of potatoes daily to the United Kingdom. In the industrialized countries, no fewer than 10-15 calories are spent to produce and distribute 1 calorie's worth of food. The US food system alone uses 17% of the US total energy supply. We therefore need policies and strategies to reduce the wastage of energy (*Seedling*, July 2007, pp. 2-7).

Such policies and strategies imply the improvement of soil fertility and the reduction of emissions of carbon dioxide and greenhouse-effect gases. If global transport remains the major producer of these gases, accounting for 14% of all emissions, agriculture accounts for the same percentage share. If one adds the emissions due to the change of land use, particularly the logging of forests and widespread deforestation, i.e. 18% of the total, one can conclude that intensive agriculture is a key factor behind global warming and climate change (*Seedling*, July 2007, pp. 2-7).

Also according to the Review by Nicholas Stern, commissioned by the British government on the economics of climate change, fertilizers are the largest single source of emissions from agriculture, followed by livestock husbandry and wetland rice cultivation, as they bring huge amounts of nitrogen into the soil, which is later emitted into the atmosphere as nitrous oxide. The same report concluded that total agricultural emissions were expected to rise by almost 30% in the period to 2020, with around half of the expected increase coming from the rising consumption of fertilizers (*Seedling*, July 2007, pp. 2-7).

The energy equation is therefore closely related to climate change and global warming. Any policy aimed at reducing fossil fuel consumption, at eliminating all kinds of wastage of energy and products whose manufacture consumes much fossil energy, such as fertilizers, and at maintaining the forest cover, will have a significant and positive impact on the mitigation of climate change. See the Joint Science Academies' Statement to the Gleneagles G8 Summit in July 2005, Global Response to Climate Change (Ragauskas et al., 2006).

The case of agrofuels should be examined in this context: are they improving the energy equation? Is their consumption reducing carbon dioxide emissions compared with oil and oil-derived fuels? Is their production displacing forest land and natural ecosystems, thereby generating additional emissions of carbon dioxide? And finally are they replacing food crops and to what extent?

BIOMASS AND BIOENERGY

Until the 20th century, biomass was humankind's main source of energy. Even today, roughly 10% of all our energy comes from biomass, i.e. far more than from any other renewable energy source or from nuclear fission.

On the other hand, at the beginning of the 20th century, many industrial materials such as dyes, solvents and synthetic fibres were made from trees and agricultural crops. By the late 1960s, many of these bio-based chemical products had been displaced by oil derivatives. The energy crisis of the 1970s sparked renewed interest in the synthesis of fuels and materials from bioresources. But this interest waned in the decades that followed as the oil price abated (Ragauskas et al., 2006).

Although biomass is often not all that renewable - e.g. the biomass sources that provide firewood to the world's poor are not being replanted - three recent developments have spurred renewed interest in biomass:

- One is the need to reduce greenhouse-effect gas emissions. The requirement for other external energy inputs during biomass processing means that it often involves some net carbon emissions – but the amount of carbon dioxide given off by burning biomass is the same as that taken from the atmosphere by photosynthesis in the first place. If biomass projects could sequester carbon, either by enriching the soil beneath plantations or by storing any carbon dioxide produced in combustion, they could become carbon negative.
- The second development is the upward movement in the prices of oil and natural gas.
- The third is the revival of concerns about the security of supply of fossil energy sources. Most nations are seeking home-based energy sources so as to depend less on political stability in the Middle East or Russia.

Biofuels are fuels derived from renewable biotic resources, such as fuelwood, charcoal, livestock manure, biogas, biohydrogen, microbial biomass, agricultural waste and by-products, energy crops (agrofuels). These sources are usually called biomass, though the phrase "energy feedstock" or agrofuels are also used for purpose-grown energy crops.

Whereas oil and coal are unevenly distributed among countries, all countries can generate some bioenergy from domestically produced biomass of one type or another. Thus bioenergy accounted for 33% of energy use in developing countries, but only 3-4% in industrial countries in 2006-2007. There are also large differences among developing regions: biomass accounted for more than 60% of final energy use in Africa, 34% in Asia and 25% in Latin America in 2006-2007 (Hazell and Pachauri, 2006).

Most biomass in industrial countries is converted into electricity and heat in plants, whereas in developing countries it is mostly burnt by rural households for cooking and heating. Biomass was in 2006-2007 the main source of household energy use for between 2 and 3 billion people in the developing world. Agriculture's own consumption of energy was relatively small – about 4%-8% of total energy use in developing countries and 3%-5% in OECD countries. This share has declined over time as gains in efficiency have reduced energy needs (Hazell and Pachauri, 2006).

Liquid agrofuels for transport (mostly bioethanol – usually abbreviated to ethanol – and biodiesel) are still relatively minor sources of energy in a few countries. Brazil and the United States are the world's biggest producers of ethanol, but while in Brazil ethanol has displaced over 40% of gasoline use, the percentage is only 3% in the United States. In 2006-2007, global biodiesel production was only about one-tenth of total ethanol production, and the European Union, especially Germany and France, is the largest producer of biodiesel (88% of world production) [Hazell and Pachauri, 2006].

Many developing countries with equatorial or tropical climates may have a comparative advantage in growing energy crops and would become major exporters of agrofuels. Even Africa has the biophysical potential to become an important producer and exporter of agrofuels. On the other hand, for many countries in the Organization for Economic Cooperation and Development (OECD), the benefits to farmers drawn for bioenergy production could be a good way to reduce the costs and market distortions of their existing farm-support and food-export policies, which in 2006-2007 totalled about US$320 billion a year (Hazell and Pachauri, 2006).

Prospects for the transition from non-renewable carbon and energy resources to renewable bioresources

In the United States, bioethanol derived from one fifth of the maize harvest at some 120 biorefineries located primarily in the Midwest (in 2007), contributed to about 2% of the total transportation fuels mix; another 0,01% was supplied by biodiesel. The US Department of Energy has set goals to replace 30% of the liquid petroleum transportation fuel with agrofuels and to replace 25% of industrial organic chemicals with biomass-derived chemicals by 2030 (Ragauskas et al., 2006).

To meet the US president's 2017 target of producing about 140 billion liters of ethanol, as stated in his 2007 State of the Union address, the entire maize crop would need to be turned into fuel. The European Union Directive 2003/30/EC (the "Biofuels Directive") adopted in 2003, targeted 2% of all petrol and diesel transport fuels to be biomass-derived by December 2005 and 5.75% by December 2010. The directive was motivated by concerns to ensure the security of the European energy supply, environmental sustainability and achievement of the Kyoto Protocol targets. These targets are certainly achievable as it has been reported that the current sustainable global biomass energy potential amounted to about 1020 joules per year, of which 40% is currently used (Ragauskas et al., 2006).

How biomass could fulfil its role as part of a portfolio of energy sources for the 21st century?

Nations have to build regulatory mechanisms that recognize the carbon benefits of biomass, through emissions pricing, a carbon tax or a combination of the two.

Intensive research needs to be conducted into both the efficient production of biomass and its conversion into useable energy. One focal point for such research should be finding ways to grow biomass quickly and in an easily processed form, while minimizing external inputs, such as fertilizer and pesticides. Another is systems engineering of farms and ecosystems, finding ways to fit biomass projects into and around present land use and possible change in farming practice.

A major attraction of biomass is that it is likely to benefit poorer countries, which tend to be in tropical regions where plants grow quickly. But this requires consideration of the local and global impact of biomass expansion. Vast tropical monocultures clearing out primary forests will benefit no one, except those who profit from selling the fuel.

Critiques have been voiced against biomass programmes in the United States where ethanol refineries often burn fossil fuel and are reliant on subsidized maize monoculture. More innovative approaches would include firing the biorefineries with agricultural waste, and feeding them with plants of many different species within the context of sustainable and cost-effective environmental policies (*Nature*, 7 December 2006, p. 654).

Currently, the global yield for all biomass crops, including woody and herbaceous crops, growing in temperate and subtropical regions, varies from some 8 dry Mg/ha/year (for willow in Sweden) to 10-22 dry Mg/ha/year (for short-rotation woody crops in the United States). Some commercial plantations in Brazil have reported up to 20 dry Mg/ha/year. A conservative global biomass average would be 10 dry Mg/ha/year, although some small-scale field trials have reported four times this level of biomass production. So, the major challenge for biomass production is to develop crops with desirable physical and chemical traits, while increasing biomass yields by a factor of 2 or more (Ragauskas et al., 2006).

An obvious target is manipulation of photosynthesis to increase the initial capture of light energy, which is at present less than 2%, e.g. through using engineering genes from plants and photosynthetic bacteria. For instance, ribulose-1,5-biphosphate carboxylase-oxygenase (RuBisCo), the plant enzyme that converts CO_2 to organic carbon by carboxylation during photosynthesis, also catalyzes a competing, less efficient oxygenation reaction. When an inorganic carbon transporter gene from cyanobacteria was expressed in plants, the more efficient carbon-fixing photosynthetic reaction of RuBisCo was favoured. In another experiment, the cyanobacterial versions of two rate-limiting enzymes in the chloroplast carbon-fixing "dark reaction" were overexpressed in tobacco, resulting in an elevated rate of photosynthesis and increased plant dry weight (Ragauskas et al., 2006).

The manipulation of genes involved in nitrogen metabolism has also been a successful approach to increasing biomass. For instance, in a three-year field trial of transgenic poplar (*P. tremula x P. alba*) overexpressing a glutamine synthase gene (GS1), tree height increased to 141% that of control plants by the third year of the study. The potential of GS1 for engineering biomass increase is further emphasized by results showing that quantitative trait loci for yield in maize and maritime pine map to the location of GS1 (Ragauskas et al., 2006).

Plants invest considerable energy in making reproductive structures, and if flowering can be delayed or prevented, this energy may be transferred into increasing the overall biomass of the plant. In addition, by delaying or shortening the winter dormancy of plants, the growth phase of plants could be extended; regulators of this process are being investigated (Ragauskas et al., 2006).

Acting on lignin and cellulose biosynthesis

Repressing a single lignin biosynthetic gene, 4-CL, resulted in a reduction in lignin content with a concomitant increase in cellulose, an effect that can be amplified by cotransformation of multiple genes. Because the efficiency of biomass conversion depends on hydrolyzing agents gaining access to plant polysaccharides, alteration of plant cell wall structure could yield important advantages. For instance, when the lignin biosynthesis gene CCR is down-regulated in poplars, the cellulose component of the plant cell wall is more easily digested by the bacterium *Clostridium cellulolyticum* and twice as much sugar is released (Ragauskas et al., 2006).

According to Vincent Chiang, probably the world's best specialist of genetically modified (GM) trees, at the University of North Carolina, Raleigh, the biotechnology aimed at controlling lignin production is well mastered; it can be used to produce more paper and ethanol. This researcher developed a technology, presented in *Nature Biotechnology* (August 1999), consisting of modifying a gene involved in the production of lignin and of reinserting it in the trees' germ cells. Thereafter tissue culture could lead to a very large number of plantlets. V. Chiang is studying the genes regulating the production of cellulose and those regulating tree growth, so as to accelerate growth and produce more cellulose. (Kempf, 2007). GM-trees offer therefore an interesting source of agrofuel.

But how about the possible contamination of natural forests by the pollen of GM trees. Forest companies have known for many years that the pollen of *Pinus taeda* could travel over long distances, but systematic studies have to be carried out. At Duke University, Durham, Claire Williams is trying to evaluate the risk of contamination by GM pollen. A 25-meter high tower has been erected in a *P. taeda* forest, and on platform located just above the tree canopy a biologist samples the circulating air and filters the pollen grains it may contain. Sampling is done at precise times, and it is repeated dozens of times during the few weeks of pollination; the analyses are completed by simultaneous observations made at sea and at other sites in the country. The objective of this work is to know for how far can pine pollen travel and fertilize its relatives in North America (Kempf, 2007).

Forestry companies are still hesitating to adopt GM trees. Only ArborGen, a subsidiary of American and New Zealand paper corporations, based in South Carolina, has shown no reluctance in working actively in this field. It is led by a former Monsanto employee, Barbara Wells, and develops GM eucalypts, poplars and pines. Susan McCord of the Institute of Forest Biotechnology, which promotes GM trees, stated: "if trees grow more efficiently, they will use less space, and this will allow a better protection of natural forests." By contrast, Anne Petermann of the Global Justice Ecology Project considers that monoculture plantations are a major cause of deforestation in the tropics (Kempf, 2007).

In the United States, the process for releasing GM trees is at standstill. However, ArborGen aims at working in developing countries, where opposition is less strong. By early April 2007, it obtained the authorization to test GM eucalypts in Brazil. It shows confidence in the success of GM trees, with respect to both agrofuel production and using forests to sequester carbon as requested under the Convention on Climate Change (Kempf, 2007).

The concept of modern biorefinery

In essence, the modern biorefinery parallels the petroleum refinery: an abundant raw material consisting primarily of renewable polysaccharides and lignin enters the biorefinery and, through an array of processes, is fractioned and converted into a mixture of products including transportation fuels, co-products, and direct energy.

A key aspect of the biorefinery concept is the imbalance between commodity chemical needs and transportation fuels. Using the petroleum industry as an illustrative example, about 5% of the total petroleum output from a conventional refinery goes to chemical products; the rest is used for transportation fuels and energy. Most visions for integrated biorefineries do not expect this ratio to change (Ragauskas et al., 2006).

The shift from petroleum hydrocarbons to highly oxygen-functionalized bio-based feedstocks will create remarkable opportunities for the chemical processing industry. For instance, the use of carbohydrates as chemical raw materials will eliminate the need for several capital-intensive, oxidative processes used in the petroleum industry. Biomass carbohydrates will provide a viable route to products such as alcohols, carboxylic acids and esters. These natural products are also stereo- and regiochemically pure, thereby reducing dependence on expensive chiral catalysts and complex syntheses currently required to selectively install chemical functionality in petrochemicals (Ragauskas et al., 2006).

As we progress from the oil refinery to the biorefinery, the challenges associated with separation will change, but not diminish, in importance. In the petroleum industry, distillation is the unit operation that dominates the refinery separation scheme. For chemicals derived from biomass, this dominance will be transferred to solvent-based extraction. This is a result of the non-volatile nature of most biomass components and the fact that other separation techniques, such as chromatography or membranes, do not yet have the same economies of scale (Ragauskas et al., 2006).

Future biorefinery operations will first extract high-value chemicals already present in the biomass, such as fragrances, flavouring agents, food-related products, and high-value nutraceuticals. Once these relatively valuable chemicals are extracted, the biorefinery will focus on processing plant polysaccharides and lignin into feedstocks for bio-derived materials and agrofuels (Ragauskas et al., 2006).

Agrofuels

There are two main types of agrofuels: bioethanol and biodiesel. Bioethanol can be obtained through fermentation by yeasts of three kinds of raw materials: products rich in or containing significant quantities of sucrose (saccharose), such as sugar-cane juice, molasses and sweet sorghum; materials rich in starch, such as grains (maize, wheat, barley) or cassava; and cellulose-rich materials (cellulose being hydrolyzed into sugars), such as forestry and agricultural residues or wastes, and grassy species. So far, bioethanol has been produced commercially only from the first two, although intensive research is being carried out to produce bioethanol from cellulose and hemicellulose or xylans. Bioethanol can be used as fuel to replace gasoline, but this requires specially adapted engines. Generally, it is blended with gasoline (10% to 25%).

Biodiesel is derived from the esterification of vegetable oils (such as palm oil, rapeseed, soybean, castor bean oils) or animals fats, or used frying oil, in order to be blended with hydrocarbon diesel (30% for instance in B30 diesel). Light fractions of vegetable oil can also be used as fuel in diesel engines or to produce electricity in small communities that are not connected to the national electricity grid.

Agrofuels versus renewable sources of energy: what could be expected?

According to Chris Somerville, director of the Carnegie Institution's Department of Plant Biology, agrofuels are not a magic bullet, but they are part of a basket of technologies aimed at meeting humankind's needs. He is of the opinion that their contribution could be important if we could obtain 1% solar efficiency on 1% of the land in the world; that would be enough to provide all transportation fuels, or about 20% of our total energy use.

Many plant species, such as sugar-cane, capture more than 1% of the solar energy that strikes them for photosynthesis. The theoretical efficiency for plants is above 6%, and for some species the efficiency could be around 3%. One per cent of global land (13 billion hectares), i.e. 130 million hectares, would be enough at 1% efficiency to supply all transportation fuels. Brazil claims it could devote 40 million hectares to sugar-cane.

The goal of the United States is to derive 30% of transportation fuels from agrofuels by 2030. That represents around 60 billion gallons or some 240 billion liters (1 liter = 0.2641 US gallon). In 2007, there were about 240 million vehicles in the United States, and only 5 million of them were burning more than 10% ethanol. Increasing this percentage requires a very large number of facilities distributed throughout the country. This can be done, according to C. Somerville, who thinks that by 2018 the cars will consume “cellulosic” fuels, i.e. derived from cellulosic biomass. Bioethanol from maize will contribute up to 15 billion gallons, but not much more.

Regarding the economics of bioethanol, in 2004 this biofuel was selling at US$1 a gallon and at that price a subsidy was necessary. Then ethanol hit US$4 a gallon in June 2006, at which time farmers were paying off their ethanol plants in a single year. By the end of June 2008, it was worth US$2.9 a gallon, and it fell down to US$1.546 a gallon by mid-December 2008.

C. Somerville considers that wind energy is underexploited. This renewable source could provide about a third of global needs. Turbines are quite effective. Geothermal energy is also underexploited. Wind energy has been initially developed in Europe, but since General Electric has been involved into it, it is moving rather rapidly in the United States. Germany made large investments in solar energy; while in agrofuels the United States are the leader technically.

Thus, the US Department of Energy (DOE) will invest US$250 million to set up and run two Bioenergy Research Centers for the development of biofuels. The centers will conduct systems biology research on micro-organisms and plants, with the aim of harnessing and improving nature’s ways of producing energy from sunlight. “This is an important step toward our goal of replacing 30% of transportation fuels with biofuels by 2030", stated Samuel Bodman (Secretary of Energy)… "The mission of these centers is to accelerate research that leads to breakthroughs in basic science to make biofuels a cost-effective alternative to fossil fuels". They are expected to be fully operational by 2009 (Burke, 2007).

Regarding the advantages and drawbacks of agrofuels derived from vegetable oils, oil-palm could produce 5,950 liters per hectare, but environmentalists consider that its expansion is fostering the destruction of tropical forests; jatropha (Jatropha curcas, Euphorbiaceae) could produce 1,892 liters per hectare from a seed oil which is non-edible and even toxic, but some consider that yields are unreliable; oilseed-rape could produce 1,190 liters per hectare, it is widely grown in Europe and Canada, and it is said to lower biological diversity; soybeans could produce 446 liters per hectare, but some consider that its expansion in Brazil contributes to deforestation in the Amazon.

UNITED STATES' AND EUROPEAN UNION'S AGROFUEL POLICIES

Transportation fuel consumption

In the United States, transportation accounted for more than two thirds of the country's oil consumption in 2006, and transportation vehicles emitted 27% of the nation's total greenhouse-effect gas emissions (a further 9% of emissions was emitted from vehicle manufacturing and motor fuel production). Within the 25-member European Union in 2006, similar patterns prevailed, with transportation consuming 37% of total oil used. Between 1990 and 2004, greenhouse-effect gas emissions (GHG) from transport increased by 32.2%, or 2% per year on average. The share of transport in total European GHG emissions rose from 17% in 1990 to 24% in 2004. Since 1990, transport sector emissions in both regions have grown more in absolute terms than any other sector (Hebebrand and Laney, 2007).

The energy consumption of the United States and the European Union far exceeds their domestic energy resources. The US transportation sector used 4.8-billion barrels of oil in 2004; the forecast by 2030 was 6.8-billion barrels of oil. Likewise the European Union's transportation sector consumed 2.4-billion barrels of oil equivalent in 2005, a figure projected to hit 2.9-billion barrels by 2020 (Hebebrand and Laney, 2007).

The appeal of agrofuels

Europeans want to reduce their use of fossil fuels, but they seem to worry less about energy security than Americans, due in part to the North Sea oil reserves. Global warming and climate change are a major issue in Europe, where agrofuels, in conjunction with other renewable sources of energy, could reduce carbon dioxide emissions. The European Union, with a combined population of about 500 million people of its 27 member countries (2008), fixed a target of using 10% of its transportation energy needs with agrofuels in 2020. This target was considered more realistic by experts than the 5.75% target for 2010. To fulfil this goal in 2020, the European Union would require 15 billion gallons of bioethanol and biodiesel. That is more modest than the 36-billion-gallon mandate that passed the US Senate in the summer of 2007. Europe lags behind the United States and Brazil in ethanol, but production of biodiesel has soared, reflecting a Europeans' preference for fuel-efficient diesel cars (Brasher, 2007a).

Individual European countries' policies vary widely depending on national priorities and resources. Germany, a major agricultural producer, has been the most aggressive, as it promoted its booming biodiesel industry by exempting the fuel from tax. But Denmark is concentrating on other forms of alternative energy (wind) rather than promoting agrofuels. Biodiesel can be made from oilseed-rape, known in North America as canola; many farmers started growing oilseed-rape because of a requirement that they take 10% of their land out of production of food crops; farmers were allowed to grow oilseed-rape on those set-aside hectares. The European Union also offered farmers a subsidy of US$25 per acre to grow oilseed-rape. Consequently, European Union countries produced 1.4 billion gallons of biodiesel in 2006, up from 928 million gallons in 2005. The trend was to phase out or eliminate subsidies in favour of mandating agrofuel usage. Germany's tax exemption was expected to end in 2012 and the Netherlands replaced its subsidy in 2007 with a mandate for 2% agrofuels (Brasher, 2007a).

Reaching the 2020 target for agrofuels would require Europeans to import as much as 20% of their agrofuel needs and to derive as much as 30% from next-generation biofuels such as bioethanol from cellulosic biomass, according to the European Commission analysis (Brasher, 2007a). See also Hazell and Pachauri (2006).

In the case of France, the 2006 energy bill reached €46 billion, i.e. 2.7% of GDP, a record level since 1985, according to a report by the ministry of industry (11 January 2007). The increase of €8 billion from 2005 bill was due to the rise in oil and gas prices, because the imported volumes remained at the same level as in 2005.

On 28 February 2006, France's prime minister announced the building of ten new plants for the production of biodiesel and bioethanol, as a result of a bid launched in 2005, so as to increase agrofuel production in 2008, and meet the requirements of incorporation of agrofuels to fossil fuels: 5.75% in 2008, 7% in 2010 and 10% in 2015. Thus, in 2008, an additional 1.8 million tons of agrofuels could be produced by 16 plants, of which six were being built in 2006. Also a research-and-development unit on biofuels was to be set up in La Rochelle.

Industrialists (Cristanol, Tereos, Abengoa, Prolea) are using oilseed-rape, sugar-beet, sunflower, wheat and maize as feedstocks. They are investing US$1 billion and the overall 2008 agrofuel production of 3 million tons, i.e. three times more than in 2006, on some 2 million hectares, was expected to decrease CO_2 production by 4 to 7 million tons of CO_2 equivalent and to create or save 25,000 jobs.

For the United States, energy security is a high priority. The country imported more than 60% of its oil (2006), a commodity that rose from roughly US$20 a barrel in 2002 to a record US$147.50 a barrel on 11 July 2008 (it fell down to US$64.52 on 22 October 2008 in London for the North Sea brent; in New York, on the same day, the price of the US light sweet crude oil reached US$66.75 the barrel, the lowest level since June 2007; by mid-December 2008, it was traded under US$45 the barrel; Bezat, 2008). Reliance on foreign supplies for a resource so critical to the economy is increasingly worrisome to policy-makers, especially given the omnipresent threat of terrorism. Political instability in many of the world's oil-exporting countries heightens this concern. Advocates see US agrofuel production as one solution in achieving energy independence (Hebebrand and Laney, 2007).

The United States' gasoline-based transportation economy relies on bioethanol, which is primarily made from its own maize starch production and fermentation. While maize-derived ethanol and oilseed rape-based biodiesel do emit less greenhouse-effect gases than fossil fuels, they are neither the most energy efficient, nor the best sustainable option given production costs and net energy yields (Hebebrand and Laney, 2007).

Amount of energy contained in the listed fuel per unit of fossil fuel input (Worldwatch Institute, June 2006)

Cellulose-derived ethanol	2-36 (theoretical)
Biodiesel (from palm oil)	~ 9
Bioethanol (from cane sugar)	~ 8
Biodiesel (from waste vegetable oil)	~ 5-6
Biodiesel (from soybean oil)	~ 3
Biodiesel (from oilseed-rape)	~ 2.5
Bioethanol (from wheat, sugar beet)	~ 2
Bioethanol (from maize starch)	~ 1.5
Diesel (crude oil)	~ 0.8-0.9
Gasoline (crude oil)	~ 0.8
Gasoline (from tar sands)	~ 0.75

Cost ranges for ethanol and gasoline production (Worldwatch Institute, June 2006)

Bioethanol from cane sugar (Brazil)	US$0.25-0.35
Bioethanol from maize starch (United States)	US$0.37-0.55
Gasoline, wholesale	US$0.38-0.70
Bioethanol from grain (European Union)	US$0.50-0.80
Ethanol from cellulose	US$0.80-1.15

In the United States, in 2007, according to the US Department of Agriculture National Agricultural Statistics Service, maize production amounted to 13.05 billion bushels, harvested from 85.418 million acres, the average yield being 152.8 bushels per acre (≃ 4,13 tons/acre, or over 10 tons/hectare), or 352,35 million tons (1 bushel ≃ 27 kg). In the European Union, according to the USDA Foreign Agricultural Service, oilseed-rape production in 2007-2008 amounted to 17.2 million tons, harvested from 6.244 million hectares (Hebebrand and Laney, 2007).

Legislation and forecasts

The European Union and the United States have each passed a legislation that mandated the incorporation of agrofuels into the transportation fuel. The European Union's effort began in 2003 with a Biofuels Directive, which called for 2% of the fuel used in the transportation sector to be agrofuels by 2005 and 5.75% by 2010. Since the directive established indicative, not mandatory, targets, the use of agrofuels only reached 1% of transportation fuel in the European Union by 2005. Germany achieved the highest level among the member states with a 3.75% rate, followed by Sweden with 2.23%. The remaining member states were below 1%. One factor explaining the relatively higher rate adoption in Germany and Sweden was that both countries chose to combine domestic production with imports (Hebebrand and Laney, 2007; *The Economist*, 2007b).

In January 2007, the European Commission issued a Biofuels Progress Report, which concluded that the 2010 target of 5.75% was unlikely to be met. The report proposed a mandatory target: agrofuels would supply 10% of the transportation sector's fuel needs by 2020. This goal was endorsed at the March 2007 European Council Meeting, but it was made conditional on the commercial availability of second-generation agrofuels and a sustainable agrofuels production (Hebebrand and Laney, 2007).

In the United States, the government required the use of ethanol as a gasoline oxygenate as early as 1990 in areas with poor air quality. However, it was not until the Energy Policy Act of 2005 that the US Congress instituted a federal mandate for agrofuel use in the transportation sector. The Renewable Fuels Standard (RFS) called for an escalation in the amount of renewable fuel sold in the United States from 2006 through 2012. High oil prices and the demand shock caused by the elimination of one oxygenate (methyl tertiary butyl ether or MTBE), along with other incentive policies, created such a favourable environment for agrofuels, that the United States had already exceeded the RFS mandate. In 2006, the country produced 4.86-billion gallons (1 liter = 0.2641 US gallon) of ethanol, a 24.3% increase over 2005. The US Department of Agriculture's projections for 2006 through 2016 predicted that, from the 2009-2010 crop year forward, more than 30% of the maize harvested in the United States will be used for the production of bioethanol. By 2016, more than 12 billion gallons would be produced (Hebebrand and Laney, 2007).

In his 2007 State of the Union address, President George W. Bush called on the US Congress to increase the RFS to 35 billion gallons by 2017. Legislators responded positively, introducing numerous proposals to raise the mandate. Congress considered a bill aimed at increasing the RFS from 5.9 billion gallons to 8.5 billion gallons in 2008, with an ultimate goal of 36 billion gallons by 2022. In addition to the federal mandate, some States have their own blending requirements. For instance, Minnesota and Montana require that all gasoline sold within their borders uses a 10% ethanol blend. Minnesota also mandates a 2% biodiesel blend with petroleum diesel. Louisiana has a similar 2% requirement for both bioethanol and biodiesel (Hebebrand and Laney, 2007).

These proposed mandate levels in the United States and the European Union exceed the amount of agrofuels that can be supplied domestically. Using production projections from the US Department of Agriculture and the European Commission's Directorate General of Agriculture, the International Energy Agency predicted that at least 20% of the cropland in both regions would be necessary to supply just 5% of domestic fuel needs by 2010. To meet the European Union's agrofuels target of 10% by 2020, 38% of EU cropland would have to be devoted to that purpose. The USDA's estimates had forecast that the maximum production capacity for US bioethanol derived from maize starch would be merely 15 billion gallons.

Scenarios for agrofuels production in the United States and the European Union for 2010 and 2020 (in Hebebrand and Laney, 2007)

	2010				2020			
	US		EU		US		EU	
	Ethanol	Biodiesel	Ethanol	Biodiesel	Ethanol	Biodiesel	Ethanol	Biodiesel
Displacement of conventional fuel, per cent (on energy basis)	5%	5%	5%	5%	10%	10%	10%	10%
Required agrofuel production under scenario (billion liters)	38.6	10.8	11.4	10.2	84.1	27.1	23.2	23.3
Percentage of total cropland area needed to produce crops for both fuels	21%		20%		43%		38%	

Should ethanol derived from cellulose become commercially viable, the area and biomass available for agrofuel production would significantly increase, since these feedstocks (e.g. switchgrass and willow trees) could be perennial, planted on marginal lands and bred for biomass volume. In a joint study, the USDA and the US Department of Energy (DOE) estimated that the use of conventional crops, crop residues, perennial energy crops, animal manure and lumber industry wastes could replace 30% of oil use in the United States. This would require significant yield increases along with the dedication of 55-million acres of cropland, idle cropland, and cropland pasture for perennial energy crops. Production costs may also be reduced via the Fischer-Tropsch process (which breaks down biomass into gas by using heat or chemicals), that would increase the biodiesel yield from oilseed crops (Hebebrand and Laney, 2007).

The most credible projections are pointing to commercial viability of second-generation agrofuel technologies within five to fifteen years. European Union's policy-makers have noted the need to import agrofuels and feedstocks if their ambitious target was to be met. For the United States, the greater availability of land and the stronger faith in biotechnology-driven agriculture to increase yields of first-generation feedstocks have led some policy-makers to be optimistic that the larger proportion of the US mandate could be met domestically. Even though, imports would be needed, with the amount depending on costs, net energy yields, tax incentives and tariffs (Hebebrand and Laney, 2007).

Observers highlighted that on 5 July 2008 the informal meeting of the European Union's 27 ministers of energy questioned the obligation to derive a significant part of transport fuel from agrofuels, because the draft directive of the European Union on renewable sources of energy was not precise enough in that respect. Although this was a key component of the package on climate change that the European Union wanted to adopt before the end of 2008, the French minister of ecology stated that "the text of the draft directive proposed that 10% of energy used for transport be derived from renewable sources of energy, and did not specifically refer to agrofuels; that was a flexibility among others". In other words, everybody had not read carefully the draft directive, while it has been repeated since the end of 2007 that the objective of the Union was to incorporate 10% of agrofuel in motor fuels by 2020. Consequently, governments could change gears and forget about this target (Caramel, 2008b).

It is true that article 3 of the draft directive does not focus only on agrofuels, but other texts cannot be ignored. A 2003 directive on agrofuels requested that member states should incorporate "5.75% of agrofuels into gasoline and gasoil" by 2010. France decided that it should reach the objective of 7% in 2010. Furthermore, the European Council of March 2007 had approved the proposal of the European Commission to reach the target of "10% of agrofuels in transport fuels by 2020". It seemed therefore that the 5 July 2008 meeting of energy ministers wanted to put aside any commitment made earlier on by the European Commission (Caramel, 2008b).

On 6 July 2008, Ferran Tarradellas, spokesman of the Energy Commissioner Andris Piebalgs, mentioned that the Commission's proposal had always dealt with 10% of renewable sources of energy, but if that objective had been translated into 10% of agrofuels, it was because "these are the realistic solution to reduce the European Union's dependence on oil by 2020". It is not too difficult to adapt motor-cars to biodiesel, while "a revolution is needed if one wishes to use electricity or hydrogen", stated F. Tarradellas (Caramel, 2008b).

On 11 September 2008, at the European Parliament's committee on industry no agreement has been reached among its members on the project of directive being negotiated on the objective of 10% of renewable sources of energy to be consumed in transport means by 2020. This target was strongly opposed by environmentalist associations. However, an intermediary target of 5% in 2015 was agreed in order to leave time for other technologies to develop and compete with agrofuels, whose impact on food prices had been underlined. The European parliamentarians stressed that the target was achievable only with the contribution of electricity- or hydrogen-powered motor-cars, as well as of second-generation agrofuels – the overall contribution being estimated at 40% (Ricard, 2008).

These two amendments, supported by all political groups, did not suit the views of the European Union's Council, where member states, instead of setting intermediary targets, preferred to have only one by 2015-2017, at which time they might review Europe's ambitions. The 27 member states tend to stick to the 10% (of renewable energy sources) target in transport, because it is closely associated with the objective of using 20% of renewable energy sources of the whole energy consumption by 2020 (Ricard, 2008).

Regarding the criteria aimed at ensuring an environment friendly and ecologically sustainable production of agrofuels, the European member states have reached an agreement that suited the interests of producing countries such as France, and those of importing ones like the United Kingdom and Scandinavian countries. Consequently, only the production of agrofuels that respects, in both Europe and other countries, biological diversity and some international social conventions (e.g. so as to ovoid deforestation or children's work), will be taken into account. The European Union's member states agreed to certify, in the first stage those agrofuels that could reduce CO_2 emissions by 35%, compared with conventional fuels. This threshold will be raised to 50% in 2017. In addition, a bonus will be granted to agrofuels derived from crops grown on marginal lands, i.e. not used for food crops. The European Parliament committee on industry was more demanding and proposed that agrofuel efficiency be raised to 45% now and 60% in 2020, but this was rejected by agrofuel-producing countries like France (Ricard, 2008).

Instead of trying to turn crops into fuel for transport, Europe would do better to burn them for power, according to Peder Jensen of the European Environment Agency. That would save the energy used in the conversion process. It would also generate more energy, since power plants are more efficient than car engines. On 26 February 2007, the agency produced a report that underlined such arguments (*The Economist*, 2007b).

Tax incentives and tariffs

In addition to fixing production targets and mandates, the European Union and the United States have encouraged the use of agrofuels through tax incentives. In the United States, this has been the case for about 30 years. Reacting to the oil-price shocks of the 1970s, the federal government instituted a tax credit for ethanol production in 1978. This had evolved into the volumetric ethanol excise tax credit, which provides a US-cent51-per-gallon tax credit for every gallon produced of ethanol-blended gasoline. A federal tax credit for blending biodiesel with petroleum diesel was introduced in 2004 at US$1.00 for each gallon of biodiesel produced from both virgin oils and fats, and 50 cents for biodiesel made from recovered oils and fats. Fuel blenders collect these incentives, authorized by the US Congress through 2010 and 2008, respectively (Hebebrand and Laney, 2007).

The European Union's member states have put varying levels of exemptions to promote the use of agrofuels. In France, there is a reduced energy tax for certain volume (quota), marketed in the country, distributed via bidding system for companies on a yearly basis; bidding is also open for non-French companies (France, Germany and Italy hold quotas entitlements). In Germany, tax amounted to US-cent9 per liter versus US-cent47 for diesel in 2007; by 2012, taxes for diesel and biodiesel will be at the same level. In Poland, new tax exemptions have slightly increased excise tax exemptions per liter of biocomponents added to fuels in 2007, but the industry opinion is that they are not sufficient to be attractive. In Hungary, excise tax payment system started in January 2007. In the United Kingdom, a 20-pence-per-liter fuel duty abatement since 2002 is not considered attractive enough (Hebebrand and Laney, 2007).

Germany pioneered tax exemptions to promote agrofuels. It first exempted pure biodiesel from the US-cent47-per-liter mineral oil tax. In 2004, this exemption was extended to all agrofuels and portions of agrofuels blended with oil. Germany also raised its tax for diesel fuel, making biodiesel even more attractive to consumers. The exemptions applied equally to domestic and imported fuels. In 2007, the government began eliminating tax exemptions for biodiesel and vegetable oils to address concerns about a possible tax revenue shortfall. However, Germany's open policy was not replicated by all European Union's member states. The wide differences in tax incentives within the Union arguably create barriers within the internal market and make it very difficult to monitor the levels of support being provided (Hebebrand and Laney, 2007; *The Economist*, 2007b).

The US-cent51-per-gallon tax credit for bioethanol and the US$1.00-per-gallon tax credit for biodiesel in the United States are akin to Germany's policy. They do not discriminate between domestic and foreign agrofuels, but a tariff on bioethanol effectively ensures that the tax credit primarily benefits domestic agrofuel producers. In 2008, the tariff was US-cent54-per-gallon, three cents higher than the tax credit. A similar barrier does not apply to biodiesel, but interest groups such as the American Soybean Association are pressing the US Congress to enact a tariff to offset the US$1.00-per-gallon tax credit (Hebebrand and Laney, 2007).

In addition to cancelling each other out, tax incentives and tariffs can be combined in a way that favours domestically produced agrofuels. In the European Union, for example, tax incentives for ethanol apply only to undenatured ethanol. As the tariff on undenatured ethanol is considerably higher than on denatured ethanol (€19.2 per hectoliter versus €10.2 per hectoliter in 2007), and as some member states only allow undenatured ethanol to be blended with gasoline, such measures aim at discouraging imports.

One should recall that the European Commission has subsidized the transformation of surplus wine into ethanol, used as chemical and fuel. In 2005, the European Commission paid €500 million or US$630 million to turn the wine glut – including 150 million liters of quality French wine and 400 million liters of Spanish table wines – into industrial alcohol, according to EC Agriculture Commissioner. While the European Union produced and consumed around 60% of the world's wine, its exports increased to more than 1.39 billion liters in 2004 from 1.2 billion liters in 1996, at an average annual value of about €4.5 billion. In comparison, exports from the United States have risen fourfold in the past decades and those from Chile and Australia by 19 times.

The European Commission's intention was to stop paying France and Spain to turn surplus wine into fuel or disinfectant and "reinvigorate" its industry to compete with the United States, Chile, Australia, Argentine and South Africa (the so-called New World wine-producing countries). The European Agriculture Commissioner had announced new measures to overhaul the European Commission's €1.3 billion wine budget of 2006.

Need for global standards

Efforts are underway to reach common standards for agrofuels, promoted in part by the automobile industry, which is keen to operate in a global market with harmonized or compatible regulations. An International

Biofuels Forum (involving the United States, Brazil, China, India, South Africa and the European Commission) is examining the development of common agrofuel standards and codes to facilitate the commoditization of agrofuels. The European Union and the United States also agreed at their June 2006 summit to focus on biofuel standards as part of their strategic energy cooperation. Additionally, cooperation on standards was an item in the March 2007 US-Brazil Memorandum of Understanding to advance cooperation on agrofuels; it stated that, with such cooperation, "greater adoption of biofuels had the potential to spur renewable energy investment, facilitate technology transfer, stimulate rural development, and boost job creation in countries around the world"; it also specified: "this initiative does not include discussion of United States trade, tariffs, or quotas" (Hebebrand and Laney, 2007).

Regulation of US fuel standards is primarily done at the State level, which illustrates how difficult international harmonization may prove to be. In the absence of international standards, countries are adopting technical requirements that may be costly and difficult to comply with, particularly for developing country producers. Moreover, the complexity of such standards could be welcomed by protectionists' interests, who would like to hide their motivations behind technical requirements.

For instance, the European Union biodiesel standard fixes the iodine level that is required for vegetable oils used in biodiesel production, which in turn determines which types of feedstocks may be used. A specification on the content of iodine is an indication of the content of unsaturated fatty acid, which provides information about biodiesel's melting point. Only rapeseed oil complies with current iodine standards; palm and soybean oils do not. The technical justification for this is that biodiesel produced from low iodine level vegetable oils is considered more stable and more suitable for the European climate. However, it appears technically feasible to include larger quantities of vegetable oils with higher iodine contents. There is some discussion over permitting a wider range of vegetable oils for biodiesel production. Proponents for expanding the range of feedstock imports that could be used in biodiesel argue that the iodine levels should be changed.

The Dutch government, for instance strongly advocates increasing European Union's imports of agrofuels and feedstocks. They see foreign competition as key in exerting downward pressure on the agrofuel prices and, as such, point to existing fuel quality standards that limit the amount of blending and the types of plant oil that could be used as one of the main obstacles blocking agrofuel use in the European Union.

However, producers, who benefit from oilseed-rape being the only European biodiesel feedstock, would like to see the specification remain (Hebebrand and Laney, 2007).

In the United States, the National Biodiesel Board (NBB) has closely scrutinized the US tax authorities' guidance documents regarding the United States' volumetric biodiesel credit. This guidance spells out the percentage of biodiesel and the technical standards for producers who would like to benefit from the volumetric tax credit. The NBB's policy is not only driven by technical interests, but also by a desire to limit the tax credit benefits to agrofuels produced in the United States from US feedstocks (Hebebrand and Laney, 2007).

A crucial factor of an international sustainability standard for agrofuels would be an agreement on how CO_2 credit determination for agrofuels should be harmonized. The magnitude of a product's "carbon footprint" depends not only on its carbon output, but also on the parameters of measurement that are established. For instance, is the carbon footprint of bioethanol measured only by its carbon emissions when burnt, or does the carbon released during feedstock cultivation also apply? At what point during agrofuel production does measuring stop? This is a very complex area for which international consensus is the most difficult to achieve. Environmentalists are also questioning the potential impact that the massive production of agrofuels would have on water availability, soil fertility, biological diversity and air quality. Concerns have also been raised about food versus fuel conflicts and negative social impacts (i.e. treatment of smallholders and workers). This debate can help steer agrofuel production in a manageable, sustainable manner. According to the World Bank, "arguably the greatest technical barrier in the coming years could be the certification of biofuels for environmental sustainability (Hebebrand and Laney, 2007).

In the European Union, it seems too difficult to reach a wide consensus on what constitutes sustainable production, given the many initiatives underway at the member-state and provincial levels. In Belgium, for instance, there are three different sets of certificate systems at the provincial level. Stakeholders supporting sustainability standards have diverse interests – from rainforest protection to banning the use of genetically modified feedstocks for agrofuels to the prevention of child labour. A multi-stakeholder process, called the Roundtable on Sustainable Biofuels was officially launched in April 2007. It aimed to develop principles and criteria related to agrofuels' environmental and social impacts as well as overall benefits in terms of reducing greenhouse-effect gases. This global feedback process will focus on such areas as biological diversity, water resources, labour and land rights, and rural development. Another attempt to arrive at international standards is underway in the G-8 Global Bioenergy Partnership Forum (Hebebrand and Laney, 2007).

EuropaBio – the European Association for Bioindustries whose mission is to promote an innovative and dynamic biotechnology-based industry in Europe – supports the initiative of the European Union to develop sustainability criteria for biofuels. EuropaBio recommended that the certification schemes be coordinated at the international level and preferably harmonized globally. Sustainability criteria should be based on the best available technologies and practices. EuropaBio does not support any unsustainable use of plant material for biofuel production, and insists that the use of biomass for that purpose should not jeopardize European and Third Countries' ability to secure its people's food supply, nor should it prevent achieving environmental priorities such as protecting forests, preventing soil degradation or erosion, and keeping a good environmental status of water bodies. EuropaBio also recommended that sustainability criteria be developed not only for the biomass used for agrofuel production, but for all energy sources, in order to avoid a competitive disadvantage for the European agrofuel sector.

While the European Union's "fundamental benchmark must be an environmental one", as EU Trade Commissioner Peter Mandelson explained, the United States' primary interest in promoting agrofuels is energy security. Moreover, the United States has strongly resisted discussing agrofuel sustainability standards at the international level. This reluctance follows its general aversion to regulations detailing production-process methods, but it may also stem from sensitivities to how its own maize ethanol may fare under such scrutiny. Indeed, compared with ethanol produced from sugar-cane, the environmental benefits of maize ethanol stand up poorly. The amount of fossil energy that goes into producing maize (through fertilizers, pesticides and machinery use), combined with the small quantity of extractable energy contained in a maize kernel, makes maize a less desirable agrofuel feedstock (Hebebrand and Laney, 2007).

While exporting countries may have concerns about environmental and social sustainability issues, these may well compete with equally strong, economic interests. The 1987 Brundtland Report on sustainable development argued that economic growth and trade could help overcome the "pollution of poverty". Developing countries are likely to argue that overtly stringent standards jeopardize their opportunities to industrialize, whereas no such constraints were placed on developed countries during their industrialization. Any sustainability criteria should offer developing countries incentives to produce sustainably rather than impose export restrictions. Carbon sequestration and carbon trading opportunities for developing countries should be explored as an alternative source of income to unsustainable agrofuel feedstock production (Hebebrand and Laney, 2007).

Conclusions

Hebebrand and Laney (2007) rightly underlined that agrofuels was not a panacea for achieving energy security, and that although domestic interests will understandably want to benefit from incentives, they should not do so disproportionately if the overriding objective of promoting agrofuels is to reduce dependence on fossil energy; in particular, if they do not offer agrofuels with relatively greater energy efficiency and greenhouse gas reduction rates. Real energy security lies in a diversification of sources, which mitigates the impact on potential supply disruptions. Until the advent of second-generation agrofuels, the most energy efficient and sustainable first-generation agrofuels should be promoted, regardless of national origin. This is not achieved through discriminatory tax incentives and high tariffs.

Global sustainability standards could point the way towards optimal biofuels and feedstocks. The reduction of greenhouse gases should be the top priority. While US interest in agrofuels is mainly driven by the necessity of achieving greater energy security, the European Union's interest, in contrast, stems largely from concerns about climate change. This divergence will not facilitate an international consensus on what constitutes sustainable agrofuel production. On the other hand, for international sustainability criteria to be effective, they must truly be global and incorporate the interests and concerns of developing countries, particularly with regard to not hampering their economic growth (Hebebrand and Laney, 2007).

BIOETHANOL PRODUCTION AND INDUSTRY IN THE UNITED STATES

Present situation and forecasts

Promoting energy independence has been a consistent theme of President George W. Bush; in his 2007 State of the Union address he mentioned: "For too long our nation has been dependent on foreign oil", and he set an explicit target of cutting gasoline usage by 20% over the following ten years. That would mean, by 2017, a market for renewable and other alternative road fuels of 35 billion gallons, displacing 15% of gasoline consumption. That target, seemingly guaranteeing huge growth in the consumption of bioethanol and other agrofuels, has sustained the wave of interest in renewable transport fuels, and encouraged a surge in the planting of maize, the unique feedstock for domestically produced bioethanol.

Indeed, bioethanol production in the United States is soaring. It rose by 22% in 2006 to 4.89 billion gallons, pulling the country ahead of Brazil as the world's biggest producer. Production capacity in 2007 was up a further 20% at 5.9 billion gallons a year, and still rising fast. In 2007, there were some 120 bioethanol plants operating in the United States, 75 more were under construction.

The industry is very diverse: small local and farmer-owned plants account for about 40% of production, while Archer Daniels Midland, the large agribusiness company, produced about 25%. The remainder is accounted by a range of other companies, including big names such as Cargill. Peter Gaw, global head of power and utilities at ABN Amro, argued that further consolidation was likely.

What will matter even more to the future of the industry, however, is technological change. It is clear that the limits of the current model of maize-based ethanol production will be reached long before the US president's target is hit. In 2006, ethanol production took 20% of US maize crop, up from 12% in 2004, and the share is still rising. Maize prices have been rising too; they have gone from about US$2.50 a bushel (1 bushel ≃ 27 kg) to about US$4 in April, although the sharp increase in maize planting by US farmers has pulled the price back to about US$3.50 by the fall of 2006. Demand from bioethanol producers is not the only reason; increased demand from food manufacturers and poor harvests have also been to blame. But it is becoming an increasingly important factor. The effect on the cost of food may not have been obvious in the United States, but it has been important in Mexico. In this country, the cost of flour tortillas went from 25 cents a pound to 50 cents in some areas. In April 2007, the government was forced to agree a price cap to last until August.

The extraordinary boom of maize-derived bioethanol has been supported by the federal government subsidy of US-cent51 per gallon (US-cent13.5 per liter), and by the fact that a growing number of States were pushing for wider use of E85, a fuel blend that is 85% ethanol and only 15% petrol. California has helped to lead the way. When the State banned the use of methyl tertiary butyl ether as a fuel additive after 2003, everyone had to use bioethanol instead to meet clear-air standards; and local refineries for the product began popping up to benefit from a State subsidy of US-cent40 per gallon at the time (*The Economist*, 2007b).

Wallace Tyner, an agricultural economist at Purdue University, pointed out that States that had introduced subsidies early, such as Illinois, Iowa, Minnesota and Nebraska, were already building lots of ethanol factories before 2004, whereas corn-belt states without subsidies, such as Indiana and Ohio, did not do much until oil prices rose (*The Economist*, 2007c).

Iowa, in the heart of the region, had 28 ethanol refineries in 2007, which produced 1.9-billion gallons a year, nearly a third of America's total capacity. Although agribusinesses such as Archer Daniels Midland have built many ethanol refineries, farmers' cooperatives and local investors have also been involved in this expansion. The first local groups to do so were in remoter areas where farmers could not obtain the best prices for their maize because of the high cost of transporting it to the market. In Iowa, that region is the north-western part of the State, which enjoys high crop yields but receives US-cent25-50 less per bushel because it is too far from the Mississippi river barges. The same logic applied in the eastern counties of North and South Dakota, in south-west Minnesota and in other parts of the corn-belt, where transporting the cereal to market is costly. It is therefore more effective to convert maize into bioethanol and send that to distant markets (*The Economist*, 2007c).

One consequence of this ethanol boom is that land prices in Iowa rose 10% in 2006, and are still climbing. Jobs are being created around the factories, and local investors that built some of the State's first modern refineries, have ploughed their profits into home improvements, college fees and farm equipment. Another consequence is the impact on livestock husbandry. Besides extracting maize starch content to be turned into fuel for cars, ethanol refineries convert the rest of the crop into distillers' grains. These contain the maize protein (gluten) and other nutrients, and are increasingly being fed to cows, pigs and chicken near ethanol factories around the country. As someone commented: "we take the candy bar out of the corn and then feed the rest to the pig". Although Iowa raises large numbers of pigs, distillers' grains work much better as feed for beef and dairy cows. According to researchers at Iowa State University, the State's refineries already churn out more than five times as much of the feed as its small stock of dairy cattle can eat. Most of those refineries, therefore, have to use a great deal of energy drying the distillers' grains so that they can be shipped to Texas and other cattle States in the South. Feeding the by-product directly to local animals would cut energy use at the refineries and transport costs for the feed. Iowans and other Midwesterners think this logic will drive a boom in the region's beef and dairy industries. Plenty of investors however view it as an excellent reason to start building ethanol refineries in Texas which has many cattle to feed (*The Economist*, 2007c).

Iowans do not seem worried by the development of second-generation agrofuels, such as cellulosic ethanol, subsidized by the federal government, because that development remains years away and also because they can benefit from leftover maize stalks and stover that can be used to produce cellulosic ethanol. For the time being, the State's farmers are planting as much maize as they can, and hoping that oil prices will remain high (*The Economist*, 2007c).

Sugar-cane cultivation in Hawaii for bioethanol production

In 2006, after so many years in which Hawaii turned its back on its agricultural history to focus its economy on tourism and real estate industries, the real estate expert, David Cole, has used his position as head of Maui Land and Pineapple, a land holding and operating company, to promote sustainable development and thereby return some farmland to production – this time for energy rather than food. In this respect, the most notorious effort is Hawaii BioEnergy, an international consortium that includes two other local landowners, Tarpon Investimentos, an investment company in Bermuda, and Brasil Bioenergia, an energy company in São Paulo. The consortium, which also involves the co-founder of the Internet portal, America Online, Stephen M. Case, and the venture capitalist, Vinod Khosla, took form in July 2006, with a view to making Hawaii, which had to pay high prices for imported fuel for a long time, largely energy independent. Indeed, the Hawaiian archipelago relies on imported oil for nearly 90% of its energy needs, making it one of the most expensive places in the United States to buy gasoline and pay for electricity and heating (Villano, 2007).

In May 2006, Hawaii passed a bill requiring that 20% of all highway fuel demand by 2020 should be provided by renewable fuels like ethanol, biodiesel or hydrogen. But 2020 seemed too far off and David Cole decided to act after a journey to Brazil during the summer of 2006. With the help of Stephen Case, he signed an agreement with Hawaiian landowners like Kamehameha Schools, an independent school system and the largest landowner in the State, and the Grove Farm Company, a 8,900-hectare sugar-cane plantation in eastern Kauai, owned by S. Case. Both businessmen also enlisted help from companies overseas, and recruited Vinod Khosla, a co-founder of Sun Microsystems in 1982, who has become one of the biggest backers of renewable energy in the world. Thus, Hawaii BioEnergy was born. Since then, these founding partners and Maui Land and Pineapple have invested nearly US$1 million in cash and recruited many full-time employees to run the company. They expected other investors to help raise an additional US$50 million to US$80 million in order to allow the company to take off (Villano, 2007).

Yet the main problem of this consortium is land. The three landowners owned about 10% of the arable soil in the State: 182,000 hectares in all. Though most of this land was fallow in 2007, the partners were planning to combine contiguous parcels and coordinate operations. These efforts were not without risk, but bioenergy looked like a profitable venture. According to Stephen M. Case, “Hawaii’s first act was agriculture, and the second act was tourism. Now it is time for the third act, Hawaii 3.0” (Villano, 2007).

Ethanol imports: tariffs and drawback provisions

In 2006, more than 434-million gallons of Brazilian bioethanol were imported into the United States. Two tariffs apply to ethanol imports, which are intended to shelter US ethanol plants from foreign competition and to deny the benefits of US domestic ethanol subsidies to foreign ethanol producers. One sets a tariff of 2.5% based on the value of the ethanol imported. The second levies a US-cent54-a-gallon duty on each gallon imported. This duty was imposed to keep foreign-produced ethanol from collecting the federal income tax credit, which has been in place for more than 20 years. The blenders credit as it is known, gives a credit of US-cent51 for each gallon of ethanol that is blended with gasoline, whether the ethanol is produced in the United States or not. Allowing Brazilian ethanol to qualify for the tax credit would subsidize Brazil's ethanol industry, but Brazil considers the US tariffs on imports violate the World Trade Organization's rules (Perkins, 2007).

Drawback provisions in US customs law date back to 1789, when the Continental Congress established them to promote jobs, encourage manufacturing and exports, according to the US Customs Service. The so-called duty drawback works in the following way: companies import Brazilian ethanol into the United States, then receive a rebate on taxes they have paid on the ethanol when they sell jet fuel for export. The drawback lumps ethanol and jet fuel together as finished petroleum derivatives, even though ethanol is not a petroleum product. One potential impact of the duty drawback is: if importers can avoid the tariff, US producers worry that they may lose out to Brazil, which can make ethanol more economically with sugar-cane and lower labour costs. The Senate Finance Committee, that is pushing to repeal the drawback, estimated that by doing so US$44 million will be added to US tax revenues over ten years (Perkins, 2007).

In 2006, US ethanol prices made importing foreign ethanol profitable. By receiving a rebate on the tariffs that were paid to import Brazilian fuel, companies could make even more money by bringing it into the United States. Dan van Zijll, who was responsible for North American imports of ethanol for Vertical, a global biofuels trading company, estimated that some large oil companies that imported ethanol from Brazil to the United States paid US$50 million to US$100 million in tariffs in 2006. By turning around and exporting jet fuel, these companies will receive a rebate on nearly all of that money (Perkins, 2007).

Robert Dinneen, president of the Renewable Fuels Association, the ethanol industry's main lobbying group in Washington, D.C., reacted by stating that the issue was no about barriers to the entry of ethanol into the United States, but it was about access to the US taxpayers' pocketbook. Brazil's ethanol industry has had 30 years of government subsidies, he added, and does not need US taxpayers' largesse. According to the Brazilian embassy in Washington, 10% to 15% of Brazil's bioethanol was exported; most of it to the United States, but this country wants to focus its future exports on Asia (Perkins, 2007).

Brazilian ethanol exports to the United States spiked by mid-2006 when methyl tertiary butyl ether (MTBE) was phased out because of groundwater pollution. The resulting demand for ethanol sent prices over US$4 a gallon at one time, compared with about US$2.50 a gallon by March 2006. High prices for ethanol made it profitable to pay the freight and import tariffs on the Brazilian fuel shipped to US ports. Van Zijll expected that the United States were to import about 200 million gallons of ethanol from Brazil in 2007 because prices had fallen by the autumn of 2007 (about US$1.70 a gallon) [Perkins, 2007].

It should be underlined that ethanol producers in Brazil have an advantage over their US competitors in that they use sugar-cane and not maize. Brazil also has lower labour costs. The following comparison of the two countries is very illustrative :

Brazil	United States
perennial crop (sugar-cane)	planted annually (maize)
five cuttings in six years	harvested annually
yields 35 tons/hectare	yields 4.2 tons /hectare (at 150 bushels/acre)
100 lbs. (about 50 kg) make a gallon of ethanol	20 pounds make a gallon of ethanol
1 acre yields 650 gallons of ethanol	1 acre yields 400 gallons of ethanol
15-16 million acres in production (2006)	92.8 million acres planted (2006)
two thirds is harvested manually	almost all is harvested mechanically
sugar-cane may be replacing soybeans	maize is replacing soybean acres
US-cent81 a gallon cost of production	US$1.03 a gallon cost of production (2006)

New maize hybrid varieties with high ethanol yield potential

In the United States, growth in ethanol demand has been prompting worries about whether maize production can keep up. While farmers responded in 2007 with the most planted maize acreage since the second world war, another way to respond to that concern is to develop higher-yielding maize varieties.

Monsanto Co., Syngenta AG and Pioneer Hi-Bred International Inc., a division of DuPont Co., held a combined 72% share of the maize seed market in 2007-2008 and are leading the filed in commercialization of breeding technologies into new hybrids. Monsanto has declared the average maize yield in the United States will reach 300 bushels an acre – double the current national average. It should be recalled that the average yield in 1970 was 70 bushels per acre; in 2007 it averaged 152.8 bushels per acre. Projecting that trend to 2030 would indicate 200-bushels-per-acre average yields. Monsanto predicted that advances in molecular breeding would push the yield up to 250 bushels per acre, and additional biotechnology gains would boost the average to 300 bushels per acre (or about 32 tons/ha) by 2030. Syngenta's head of renewable fuels for North America, David Witherspoon, stated molecular breeding allowed plant breeders to identify desirable genetic traits and select successful hybrid crosses in the laboratory, speeding up the improvement in maize hybrids (*Ethanol Producer Magazine*, October 2007).

Pest and weed control is indispensable to achieving higher-yielding maize varieties. Monsanto has developed triple-stack traits with the glyphosate tolerance and two types of insect resistance in the same plant. Pioneer expected to introduce its new line of engineered hybrids, Optimum GAT, in 2009; the hybrids will combine traits for glyphosate tolerance with tolerance to the family of acetolactate synthase herbicides, expanding the spectrum of weed control available to farmers (*Ethanol Producer Magazine*, October 2007).

All three companies stated the next round of maize improvement would feature greater drought tolerance and improve nitrogen utilization. In addition, Pioneer tries to develop maize hybrids for each growing region of the country, with improved ethanol yield potential per bushel, as well as better feed value of the distillers' dried grains. Pioneer brand hybrids with above average ethanol yield potential are designated as High Total Fermentable (HTF) ethanol hybrids. These hybrids deliver higher quantities of fermentable starch, resulting in higher ethanol output. Research showed there could be up to a 7% variation in ethanol yield potential among different hybrids. Many Pioneer HFT hybrids contained Herculex insect protection traits to reduce insect damage to grain and prevent molds and mycotoxins. This helps maximize grain yields and ensure a more consistent supply of high quality grain. The two other seed companies are also promoting high fermentable starch maize hybrids. Syngenta's Garst brand is promoting them as ExtraEdge ethanol varieties, while Monsanto calls its programme Processor-Preferred High Fermentation Corn (*Ethanol Producer Magazine*, October 2007).

Syngenta has filed an application for a new genetically engineered maize line, intended to facilitate ethanol production, to the European Food Safety Authority (EFSA). This transgenic 3272-maize, for which the company is seeking commercialization, expresses a heat-stable version of alpha-amylase derived from *Thermococcales* bacteria in the endosperm of maize kernels, but not in pollen. This enzyme breaks up the alpha 1-4 glycosydic bonds of starch, which is the second step of the so-called dry-grind process for ethanol production, after having boiled the grains. This transgenic maize will be planted outside Europe, according to documents submitted by Syngenta to the EFSA. While by-products of the dry-grind process are sold as feedstuff and thus can eventually feed animals, Syngenta applied not only for import of the 3272-maize for industrial use, but also for use in the food and feed chain.

Monsanto ran trials in 2003 and 2006 at 14 ethanol plants where growers segregated high fermentable maize varieties and tested them in plant runs that lasted from five days to two weeks. The company found an average increase in ethanol yield of 2.7% with a range of 2%-4%. Fifty ethanol plants were in the network of process-preferred processors, of which 20% were offering premiums between US-cents 5 and US-cents 10 per bushel on the 2007 harvest (*Ethanol Producer Magazine*, October 2007).

In addition, Sandia National Laboratories and Monsanto announced a three-year research collaboration with a view to aligning Sandia's capabilities in bioanalytical imaging and analysis with Monsanto's research in developing new seed-based products for farmers including maize products that may produce more ethanol per bushel (Burke, 2007).

Aurora Co-op was paying a US-10-cent premium on any Monsanto-Dekalb high fermentable maize variety and 8 cents on other high-starch varieties. The Co-op handled the high-starch varieties at four of its 40 locations. The Co-op originated grain for Nebraska Energy LLC's 50 MMgy ethanol plant in Aurora, Neb. The Co-op received maize in the fall of 2007 at its new 1-million-bushel facility alongside the site of the planned Nebraska Energy expansion. The expansion project included a first 110 MMgy for completion in the spring of 2009, and a second 110 MMgy to follow suit. When the expansion scheme reaches 270 million gallons of ethanol, 100 million bushels of maize a year will be needed, i.e. 1.9 million bushels per week (*Ethanol Producer Magazine*, October 2007).

Agrivida is a biotechnology start-up created in 2002 in Cambridge, Mass., by a chemist Michael Raab, with a view to increasing by 50% the yield of ethanol per hectare of cultivated maize, while at the same time reducing by over 20% the costs of transformation of starch into ethanol. M. Raab developed a transgenic maize variety, called GreenGenes, that produces enzymes which degrade leaves and stalks, and not just starch. These enzymes are only activated after the plant is harvested. Once the plant is cut, leaves are exposed to heat, between 70° C and 90° C, which induces the production of enzymes. The latter transform cellulose into sugars (saccharification), that will be fermented into ethanol (Alberganti, 2006).

Agrivida has been carrying out greenhouse trials by the end of 2006 and was planning field trials by mid-2008. Thereafter, the process of approval by the US FDA and other federal bodies will last about three years. During field trials and biosafety tests, it should be demonstrated that the new GM variety does not “contaminate” crops growing nearby. Consequently, commercialization was not foreseen before 2011 (Alberganti, 2006).

Agrivida has collected US$1.3 million, half being provided by public funds (in particular by the National Science Foundation) and half by private entities. It employed 10 persons at the end of 2006, but the staff could double by mid-2007. Michael Raab was 33 years old and was distinguished as one of the young innovators in 2006 by the Massachusetts Institute of Technology (Alberganti, 2006).

Boom and bust of the US bioethanol industry

In 2008, the annual turnover of the US bioethanol industry was of the order of US$32.5billion. It started to produce bioethanol as a fuel in the early 1970s – the Arab oil embargo period – with two main reasons: lower dependence on oil imports and help farmers finding another source of income. Kevin Allison and Stephanie Kirchgaessner of the Financial Times (22 October 2008) quote among the pioneers of the US bioethanol industry Jeff Broin from Minnesota, who set up with his father an ethanol still on their farm with a view to selling maize-derived fuel to the few companies that started blending ethanol into gasoline. Later on, this family bought another plant in South Dakota to widen their business.

Farmers of the Midwest corn belt were supported by a coalition of 20 Democratic and Republican senators of the US Congress, while the big oil corporations were opposed to the ethanol industry, considered as a potential rival. The debate went on during the 1980s and 1990s in Washington, D.C., until President George W. Bush clearly supported the bioethanol industry in 2001. Chuck Grassley, a Republican senator from Iowa, stated after the terrorist attack of September 11, 2001: “Isn’t it more sensible to spend US$140 a barrel for ethanol than it is to ship US$140 over to Arabia and let their Wahabis be trained to kill you and me?” (Allison and Kirchgaessner, 2008).

Also rising oil prices made bioethanol and other alternatives fuels more attractive. Investors followed suit: in May 2003, Morgan Stanley Capital Partners, the private equity arm of the US investment bank, acquired Aventine Renewable Energy, an ethanol producer with plants in Illinois and Indiana, for US$75 million. Only seven months later, it paid itself nearly twice that in dividends (Allison and Kirchgaessner, 2008).

In 2004, the US Congress passed a law giving refiners an incentive to blend ethanol with gasoline by letting them claim a US-cent51-per-gallon tax benefit on each gallon of ethanol they used. In 2005, the price of a gallon of petrol had risen over the US$3 threshold. In addition, the ethanol industry claimed as a renewable source of energy bioethanol could help reducing greenhouse-effect gas emissions. Legislators were therefore working on a new law that would require gasoline producers to blend billions of gallons of ethanol into petrol each year. Barack Obama, as a freshman Democratic senator from Illinois, a leading maize-producing State, was a strong supporter, and he stated in a Senate speech: "instead of continuing to link our energy policy to foreign fields of oil, it should be linked to farm fields of corn". However, New York's Senator, Chuck Schumer, disagreed: "there is no sound public policy reason for mandating the use of ethanol – other than the political might of the ethanol lobby". Also big users of maize, such as meat processors, complained bioethanol would lead to higher maize prices (Allison and Kirchgaessner, 2008).

But after fuel additive known as methyl tertiary butyl ether (MTBE) was banned in the United States because of its pollution power of ground water and aquifers, bioethanol was adopted as a substitute by the oil industry and it received the support of the American Petroleum Institute, the industry's leading lobby group. This support changed the political context at the US Congress, as stressed by Robert Dinneen, president of the Renewable Fuels Association, the ethanol industry's main lobbying group in Washington, D.C. President G.W. Bush signed the Energy Policy Act of 2005, which required refiners to blend 7.5 billion gallons of agrofuels into gasoline by 2012. Thus a multi-billion dollar market was created (Allison and Kirchgaessner, 2008).

Investors were therefore attracted by the bioethanol industry. For instance, in November 2005, Cascade Investments, Bill Gates' private investment company, paid US$84 million for a 27% stake in Pacific Ethanol, a California group whose shares had begun trading on the Nasdaq stock market that year. It had a profitable business marketing bioethanol made by other producers but had yet to produce the fuel itself. Also two New York hedge funds – Greenlight capital and Third Point – invested about US$75 million in Biofuel Energy, a Colorado ethanol producer. Thomas Edelman, a Wall Street banker, and oil and gas executive was appointed as chairman. In May 2006, Thomas H. Lee Partners, a Boston private equity group, took an 80% stake in Hawkeye Renewable in a deal that valued the company at US$1 billion. Those early investors into the US bioethanol industry, before the spike in prices, after the energy bill was signed in 2005, made huge returns. For instance, the shares of VeraSun of South Dakota initially rose 34% (Allison and Kirchgaessner, 2008).

In June 2006, due to oversupply of ethanol, prices started to fall and by September 2006 bioethanol that had sold for US$4 a gallon in June was trading at US$1.75, according to DTN, a commodities research group. Maize prices, meanwhile, were rising sharply, driven by increased demand for the crop for use in ethanol production and the rising cost of oil. They were above US$3.50 the bushel by the fall of 2006 (they peaked at US$7 the bushel in April 2008). Investors started to retreat. After its first ethanol plant came into operation in October 2006, falling bioethanol prices and the rising cost of maize, Cascade Investments began divesting its stake in Pacific Ethanol, whose shares fell from a peak of US$42 on 11 May 2006 to US$15 in September 2006. In April 2008, Pacific Ethanol's shares sold for less than US$4, and Bill Gates has lost at least US$37.9 million on the investment. When Biofuel Energy finally went public in June 2007, it was forced to cut its offer price twice in one week (Allison and Kirchgaessner, 2008).

According to an analysis by the *Financial Times*, six of the biggest publicly traded US ethanol producers had lost more than US$8.7 billion in market value since the peak of the ethanol boom in mid-2006 and the beginning of October 2008, despite billions of dollars of government support of the industry. The analysis concluded "corn ethanol has undergone a rapid boom and bust". Allison and Kirchgaessner who made the analysis compared the ethanol investment frenzy to the dotcom mania of the late 1990s. More than US$11.2 billion had been spent since 2005 on tax breaks for companies blending bioethanol into gasoline. Billions more had been spent on direct State and federal subsidies for US ethanol production. The Financial Times quoted Bob Starkey, a fuels analyst at Jim Jordan & Associates, a research group in Houston: "we're looking at an industry that's cost US$80 billion to get to this point" (Allison and Kirchgaessner, 2008).

Robert Dinneen, president of the Renewable Fuels Association, recognized: "There was a period of growth in the industry, and the economics were uncharacteristically favourable. People invested thinking every year was going to be like 2006, when history would tell you that was an anomaly. Clearly, there was a lot of Wall Street money coming in – and I think it was with unrealistic expectations". However, he still believed that bioethanol represented an opportunity for Americans to invest "here at home". He stated: "I'd challenge you to find any energy resource today that isn't dependent on government support" (Allison and Kirchgaessner, 2008). One may predict that maize-derived bioethanol will continue to be produced in the United States, but most probably with more reasonable expectations about returns on investments, while trying to decrease subsidies and to increase fair competition with fossil energy sources of energy.

By the end of 2008, the price of bioethanol fell as sharply as that of oil : US$1.546 the gallon on Chicago market, on 12 December 2008, compared with US$2.9 on 27 June 2008. The barrel of oil was being traded at around US$46 by mid-December 2008 (Faujas, 2008). Consequently, 16 bioethanol producers, including the US second biggest, Verasun, requested the protection of the US law on bankruptcy, that enables them not to pay their debts and fulfil their contracts, e.g. pay the maize purshased from farmers of the Midwest, who also suffered from the fall in the prices of their crop. President elect Barack Obama will have to decide whether these farmers should be assisted through subsidies, or industrialists be supported through the authorization of imports of bioethanol from Brazil (that is made from cane sugar and is more competitive than ethanol made from maize starch) [Faujas, 2008].

In Europe, the situation was not as bleak, but the French government, for instance, which initially planned to eliminate by 2012 the subsidy to bioethanol production (€0.27 per liter), had to review its position and maintain the subsidy at €0.21 per liter. According to the president of the National Trade-Union of Agricultural Alcohol Producers (syndicat national des producteurs d'alcool agricole, SNPAA), bioethanol producers were holding their promise to supply in 2010, 7% of France's energy needs; they therefore expected the French government to fulfil its commitments and to support a growing industry (Faujas, 2008).

PRODUCTION OF AGROFUELS FROM GENETICALLY ENGINEERED CROPS: AN OPPORTUNITY FOR EUROPE?

In 2006, the European Union Committee of the United Kingdom's House of Lords published a report concerning The EU strategy on biofuels: from field to fuel (Bevan and Franssen, 2006).

Genetically engineered or modified (GM) crops can make a contribution to biofuel production, primarily because of their higher yield per hectare, in a situation when the acreage available for cultivation will be a limiting factor. Indeed, any agricultural technology that is yield enhancing and/or cost-reducing, and which has the potential to make crops like oilseed-rape and sugar-beet more competitive as a source of biofuel, should be considered.

The European Union's support levels for sugars have come down significantly and as a result of trade agreements imports of sugar from developing countries may begin to enter the EU in significant volumes. This will reduce the attractiveness of growing sugar-beet in the United Kingdom. In order to remain competitive in this new market, sugar producers will need to draw on all available cost-reducing and productivity enhancing technologies, and it will be the cheapest delivered price and global supply/demand balances which will drive the business. If public opinion – and food industry practice – permit change to take place, processors may favour cost-reducing technologies based on genetic modification, for instance through the use of GM herbicide-tolerant sugar-beet. In the United Kingdom, two crop species deserve careful consideration : oilseed-rape and sugar-beet (Burke, 2007).

Oilseed-rape

A calculation on how much more oilseed-rape is required to achieve the 5% inclusion rate into diesel fuel committed by the UK government in 2006 suggests around 500,000 hectares – or almost double what is currently grown. This is possible although difficult, since it would require oilseed-rape to be grown more often in a rotation. Currently, oilseed-rape is grown every 3-5 years on a typical field to avoid club root and other brassica diseases. To meet the required amount of oilseed-rape grown in the UK, the rotation would have to be compressed to 2-3 years, with all the associated disease problems. However, less land would be required if it were possible to radically increase yields. The non-optimized GM oilseed-rape varieties trialled in the UK increased yield by an average of 14%. This could help achieve the biofuel obligation. Indeed there are the beginnings of commercial development. For instance, Monsanto UK is a member of North East Biofuels, a cluster based in North-East England promoting the development of agrofuels in the region, including biodiesel from oilseed-rape. Monsanto also worked with Wessex Grain that aims to develop bioethanol production from wheat grain and other sources of starch (Burke, 2007).

Sugar-beet

GM glyphosate-tolerant sugar-beet, as a potential agrofuel crop species, offers a substantial economic advantage: approximately 10% (£2/ton) reduction in the production cost of beet is attainable, due roughly equally to reduced input costs (herbicides) and increased yield (absence of phototoxicity). Crop management strategies have been developed to mitigate any adverse effects on farmland biodiversity. There is no longer any rational case why this particular GM crop need have any adverse environmental impact in the British farmland. Indeed, it could be managed to be more favourable to farmland birds than the conventional crop, whilst maintaining most of its economic advantage (Burke, 2007).

The conventional sugar-beet crop is declining in area and under severe economic pressure due to European sugar regime reform. Retention of spring crops is important to maintain landscape diversity, with its associated environmental benefits, in a British landscape nowadays dominated by autumn crops (Burke, 2007).

The first bioethanol plant is being built near Downham Market in Norfolk by BP, DuPont and British Sugar, and is designed to produce 70 million liters of fuel a year, using beet surplus to quota. Butanol is expected to be introduced in all 1,250 BP filling stations by 2010. Any larger scale development is predicated on wheat as the feedstock. However, such a development would exacerbate problems of autumn crops dominating the landscape and would compete directly with the forecast increasing global food demand in the medium term. With two existing sugar factories about to close, it is regrettable that there is not an opportunity to respond to the medium-term economic scenario. Development of an agrofuel industry would also change the design of any future beet processing plants (Burke, 2007).

Other possible approaches

At the Rothamsted Agricultural Research Station, marker-assisted selection breeding techniques are used by Angela Karp to improve the qualities of willows for biofuels. As custodian of the National Willow Collection, she is using molecular markers and working with molecular biologists to help develop more efficient varieties for the future (Burke, 2007).

GM crops such as GM rape and GM sugar-beet can be sources of biofuels. Any environmental problems could be contained and there are no human health issues. But could such use of genetic engineering escape the stigma that has been applied to these GM crops? The 2006 Eurobarometer poll has been completed by a new review of consumers' opinions over the last 10 years: GM *foods: what Europeans really think* (see Burke, 2007). Its conclusions are rather different from the concerns which are commonly expressed, particularly by the environmental non-governmental organizations (NGOs) and can be summarized as follows:

1. People generally answer attitude questions in their roles as citizens rather than as consumers. When they think and act like consumers, GM is a relatively insignificant consideration and negative attitudes can often be passed over in favour of lower prices or other consumer benefits. Fears about potential GM dangers are not well-founded on any experience or evidence that such dangers are real.
2. The public generally admit that they do not feel well enough informed about GM foodstuffs and there appears to be widespread misunderstanding of what genetic modification actually means.
3. Real concerns are not high when it comes to purchase decisions and any actual behaviour appears not to be influenced about GM foods safety.
4. Opposition to GM foodstuffs in the United Kingdom has been declining due to lack of scientific evidence of any actual damage, in sharp contrast to other food-related issues (such as sugar and fat content, and its association with obesity).
5. On the basis of the research evidence, phrases like "overwhelming opposition" and "massive consumer rejection", which have been used in the media and by some politicians in relation to public attitudes to GM foods, present a misleading impression of what the research is actually saying, especially in the United Kingdom, e.g. FSA annual surveys and British Social Attitudes annual survey.

Despite these conclusions, there is still reluctance based partly on resistance to the dominance of the European food chain by North American companies, partly on "unknown unknowns" over possible risks to health and the environment, and partly on the absence of any real need (Burke, 2007).

BRAZIL'S SUGAR INDUSTRY AND BIOETHANOL PRODUCTION

World sugar production

In 2005 and early 2006, sugar, the best performing commodity, was poised to beat returns on bonds, stocks and oil for a second straight year. Prices were soaring as record gasoline costs prompted Brazil, the world's biggest sugar producer, to devote more than half its crop to ethanol production to meet a goal of eliminating gas-fuelled cars in four years. A drought in Thailand, the second-biggest exporter, and a 50% rise in China's demand in the past decade were compounding factors. Sugar climbed up 60% in 2005 and was up 12% at the beginning of 2006. Raw sugar for May 2006 delivery closed at US-cent16.44 a pound on the New York Board of Trade in March 2006. The record was US-cent66 a pound in 1974.

Global sugar production fell short of demand in 2006 by twice as much as initially foreseen as world stockpiles dwindled and consumption grew, according to the London-based International Sugar Organization. The shortfall was estimated at 2.23 million tons. The booming economies of China and India contributed to the shortfall. India, the world's second-biggest producer and biggest consumer of sugar, became an importer in 2005, after two years of falling harvests, shipping in 2 million extra tons. China, the world's second-biggest consumer, was trying to stem prices gain by selling almost its entire one million tons of sugar reserves at auction. Consumption of sugar in China increased almost 50% over the decade 1995-2005, according to the US Department of Agriculture. Inventories were halved as rising demand for its use in food and soft drinks outpaced production.

In Brazil, the world's biggest user of ethanol, half of the sugar produced is devoted to making fuel, or about one-tenth of the world's annual production of 148 million tons. A 1% increase in Brazilian ethanol production removes as much as one million tons of sugar from world supplies, according to Sergei Gudoshnikov, a senior economist at the International Sugar Organization. With prices rising so fast, there is a danger that global sugar consumption growth may slow as some developing countries cut import, according to F.O. Licht, which has provided sugar data to refiners and traders for 130 years.

Brazil's bioethanol industry

At the dawn of the automobile age, Henry Ford predicted that "ethyl alcohol is the fuel of the future". Brazil is already there; it has taken 30 years of efforts and several billion US dollars of incentives and it has involved many missteps (Rohter, 2006).

The United States and Brazil are, by far, the dominant producers of bioethanol worldwide, as they together account for about 79% of the global production. They also dominate the global export production of the crops from which ethanol is produced. Thus, the United States contributes to about 70% of global maize exports, while Brazil that makes its bioethanol from sugar, accounts for 60% the raw cane sugar traded worldwide (*Seedling*, July 2007, pp. 20-24).

Brazil became a major sugar exporter at the end of the 1980s when its sugar sector was liberalized. Foreign investment started to flow into the country, thereby expanding the area and scale of sugar production, and increasing the industry's exports. But Brazil's domination of the global sugar trade became more obvious during the late 1990s and at the beginning of the 21st century. In 2004, Brazil won a key case at the World Trade Organization against the European Union (EU) sugar regime. It was considered a serious blow to the long-standing colonial trade and production routes, as well as to the EU's heavily subsidized export production. As a result, sugar industries in Africa, the Caribbean, the Pacific (ACP countries, associated with Europe through the Lomé Convention), which were sustained by preferential access to the European Union, are in steep decline. The disappearance of guaranteed volumes for export and prices has led to the lack of incentives for improving the sugar industry; yields fell down, sugar mills closed down and thousands of jobs were lost. In addition, these countries could not subsidize their sugar industry, as the European Union or the United States were doing. Meanwhile, Brazil's sugar production was booming. According to the projections of the International Sugar Organization, MECAS (05) 20, November 2005, for the total exports during the 2005-2006 harvest (October and September), out of 46.5 million tons of raw cane sugar Brazil contributed 19.1 million tons, or 41.08% of the total amount. In fact, Brazil's sugar exports have continued to rise rapidly. In 2005, the country shipped 18.1 million tons at an average price of US$215.95 per ton, for a total of US$3.9 billion. The previous year, shipments had amounted to 15.8 million tons at an average price of US$167.89 per ton, adding up to US$2.6 billion (Morceli, 2007).

The country's share of global raw sugar exports surged from 7% in 1994 to 62% in 2006 and, over the four-year period 2004-2008, its exports of sugar and bioethanol increased by 243% (*Seedling*, July 2007, pp. 20-24).

In 2007-2008, Brazil was the world's second-biggest producer of bioethanol behind the United States. In 2007, it produced 18 billion liters from cane sugar, 83% being consumed domestically (the National Sugarcane Agro-Industry Union estimated annual production would reach 30 billion liters in ten years), as well as about 200 million gallons of biodiesel from soya, castor bean and palm oils. It is also carrying out many trials in order to produce biodiesel from sunflower, peanuts, Jatropha, animal fats and used frying oil.

In 2006, it exported 793 million gallons of bioethanol (an increase of only 8.33% over 2005), half of this volume directly to the United States, and part of it through Central American and Caribbean States. Brazil also exports to Japan, the Netherlands and Switzerland, and 3% of its exports to Venezuela. The average price was US$459.95 per cubic meter (a 42.43% increase over 2005) and the income was US$765.5 million (a 53.9% increase over 2005) [Morceli, 2007]. Biodiesel trade was not significant.

For the 2006-2007 harvest in the Center-South of the country 19 new industries brought their contribution and 11 of them were located in the State of São Paulo. About 50 new plants being built in the States of Goiás, Minas Gerais, Mato Grasso do Sul, Paraná, Rio de Janeiro and São Paulo were expected to process 75.5 million tons of sugar-cane in the 2011-2012 crop year. In fact the capacity of the country was estimated at 400 sugar and alcohol plants, milling over 225 million tons of sugar-cane (Morceli, 2007). Brazil could thus transform ethanol into a major international commodity with the cooperation of other bioethanol-producing countries.

Most Brazilian motor fuel is gasohol, which by government mandate is currently gasoline with 23% ethanol (2007-2008). Ethanol from cane-sugar fermentation has been powering cars in this country on and off since the 1930s, and with government backing since the OPEC price rises in the 1970s. Next to the gasohol pumps at the petrol stations are pumps that offer pure ethanol.

For the sake of comparison, the United States, the world's biggest producer of bioethanol, has produced 5.9 billion gallons in 2007 and was building a production capacity of 6.6 billion gallons. The total of installed capacity will soon reach some 13 billion gallons. In 2006, the United States imported more than 434 million gallons of bioethanol and 48 million gallons of biodiesel. It exported almost no bioethanol and about 35.5 million gallons of biodiesel.

One fifth of the maize harvest was used in 2007 to produce bioethanol and some 120 biorefineries were working to transform and ferment maize starch into the agrofuel. Another 75 biorefineries were being built in 2007. The number of service stations that delivered E85, i.e. gasoline containing 85% of bioethanol, was 1,200 by mid-2007, compared with 750 in 2006. They supplied more than 4.5 million flex-fuel cars, according to the data of the National Ethanol Vehicle Coalition. All the bioethanol produced in the United States in 2007 made up only 2% of all the fuel consumed in transport. Biodiesel made up 0.01%.

Mastering the whole chain of bioethanol production

According to Edmar Fagundes de Almeida, professor at the Rio de Janeiro Federal University, Brazil has been able to master the whole chain of production of bioethanol and has become a world leader (Gasnier, 2007).

Sugar-cane covers 7.8 million hectares or 5% of cultivable land, including over 4 million hectares devoted to ethanol production (Gasnier, 2008b). The State of São Paulo, where mechanization of sugar-cane cultivation is increasing rapidly, provides 60% of bioethanol. According to specialists, the extension of plantations would not be a threat to the Amazonian forests, because the country has about 90 million hectares of land available. The Centre of Cane Technology (CTC), located in Campinas, São Paulo State, financed by 140 industrialists of sugar and ethanol, is in charge of optimizing sugar-cane production and transformation and includes 150 researchers. In addition, the CTC provides its shareholders with a satellite survey of their plantations. The aerial photographs, taken every two months, allow for the planning of maintenance of the fields and, for instance, indicates when and where to use herbicides and assesses the volume of the future harvest. Jaime Singuerut, in charge of strategic development at the CTC, stated: "our technology is the most advanced in the world" (Gasnier, 2007).

The Brazilian government introduced its original "Pro-Alcohol" programme in 1975, after the first global energy crisis, and by the mid-1980s, more than three quarters of the 800,000 cars made in Brazil each year could run on cane sugar-derived ethanol. But when sugar prices rose sharply in 1989, mill owners stopped making cane available for processing into alcohol, preferring to profit from the hard currency that premium international markets were paying. Brazilian motorists were left in the lurch, as were the car makers that had retooled their production lines to make alcohol-powered cars. Ethanol fell into discredit, for economic rather than technical reasons (Rohter, 2006).

Beginning in 2000, due to some government incentive programmes such as, for instance, the so-called "green fleet program" that encouraged the use of motor-cars consuming ethanol, there was some growth albeit incipient of these cars, so that by 2003, 4.61% of all cars sold in the country were ethanol fuelled. Volkswagen's release of flex fuel cars in November 2003 was a real landmark. Since then, the sales of cars that can either consume gasoline or hydrated alcohol have grown substantially. In 2006, 622,508 alcohol or flex fuel units were sold during the January-June period, out of a total of 843,521 cars, i.e. 73.80% (Morceli, 2007).

Flex fuel cars were not manufactured to use only ethanol as fuel, despite the alcohol producers' efforts to "sell" that idea. The technology was developed to give consumers greater flexibility of choice, keep them from depending on a single fuel and enabling them to use the fuel that best met their needs from the economic and environmental standpoints. Another important point is the motivation of the automobile industry. Consumers do not actually have much choice, since the industry, for many models, only offers the flex fuel engine. The overall objective is to build the so-called universal engine, whereby the same platform can be used in countries that mix 20% ethanol to gasoline like Brazil; 10%, 5%, 7% like the United States; 3% as proposed for Japan; or nothing at all, as in most countries. With the addition of flex fuel cars to the alcohol car fleet, which was almost being discarded due to obsolescence, there were new hopes for hydrated ethanol consumption in Brazil (Morceli, 2007). See also Morris (2006); Rohter (2006).

In 2007, 83% of the new cars were flex-fuel powered, 17% of fuels consumed was ethanol, also sold as a mixture (23%) with gasoline. Brazil had therefore succeeded to partly substitute oil/gasoline with bioethanol. During the 1979-2000 period, the country saved US$43.5 billion by reducing petroleum imports. These savings were particularly important, since that period corresponded to one of the darkest in Brazilian economic history when the country could not import goods essential to its development, because of lack of hard currency (Morceli, 2007).

"The rate at which this technology has been adopted is remarkable, the fastest I have ever seen in the motor-car sector, faster even than the airbag, automatic transmission or electric windows", stated Barry Engle, president of Ford Brazil. “Renewable fuel has been a fantastic solution for us”, stated Brazilian minister of agriculture, Roberto Rodrigues, in March 2006, in an interview in São Paulo, capital of São Paulo State, where Brazilians have cultivated sugar-cane since the 16^{th} century. In 2030, the country could produce 20% of the world’s agrofuel, i.e. 130 billion liters, thanks to an advanced technology. Not only will Brazil respond to the global increase in ethanol use, but also it will meet the constant growth of internal demand. This expansion has also an important social impact because the production and use of bioethanol employs over 1 million Brazilians (Rohter, 2006; Gasnier, 2007).

One should also mention that in 2006, Brazil became self-sufficient for oil, production and consumption being balanced at 2.3 million barrels of oil per day. Furthermore, the country is poised to become a big producer and exporter of oil. In addition to the Campos field that Petrobras has been exploiting for 40 years, the discovery in October 2007 in the Santos basin of Tupi field, that may contain 5 to 8 billion barrels, would raise Brazil’s reserves up to 11.7 billion barrels of oil. This means that Brazil would own the world’s third biggest reserves. Petrobras has already become the third biggest company of the Americas, behind Exxon Mobil and General Electric, and ahead of Microsoft. Its value on the stock exchange was close to US$300 billion by mid-2008 (Gasnier, 2008a).

The exploitation of the new resources would be justified only if the price of oil remains high. Although Petrobras has a good know-how regarding the exploitation of offshore oil deposits (250 km from the coast) and was able to dig wells down to 2,777 meters (in 2007), it will have to overcome technological problems in the case of the Tupi field which lies at 6,000 meters under a 2,000 meter-thick salt layer. Petrobras has also launched a plan of modernization of its fleet of tankers, ordering 146 new vessels for a total cost of US$5billion over six years. The number of refineries must also be increased and the company has initiated its biggest investment concerning the petrochemical complex of Itaborai Comperj, 45 km from Rio de Janeiro: US$8.3 billion until 2012 and creation of 170,000 direct and indirect jobs (Gasnier, 2008a).

Brazilian cars burning gasoline, natural gas and ethanol

Brazil’s car-builder Ricardo Machado has commercialized a new car, named Obvio, that burns gasoline, natural gas and ethanol or any combination of the three. A separate version will run on electricity only. When this Brazilian “trihybrid” hit the San Francisco auto show by the end of 2005, Machado had to resort to using crowd-control measures (Margolis, 2007).

The Rio de Janeiro factory began pre-production in 2007, and the first batch of 50,000 Brazilian mini-cars was scheduled to roll off the docks in the USA in 2008. More than 30 dealers have queued up. Two more deals – 70,000 cars for Europe and an additional 30,000 for Japan, and a plan to ship stripped-down cars for assembly to China – were also in the works. By the end of the decade, Machado's factory could be turning out more than 200,000 cars a year (Margolis, 2007).

The Obvio is partly the product of more than a quarter century of Brazilian efforts to promote agrofuels. The Obvio makes use of virtual fuel sensors, developed by Brazilian engineers, that cue the engine to adjust to the exact blend of gasoline and alcohol in the tank at any time. Machado, a lawyer and former real-estate developer, added an extra-pin: his crew converted the powerful 1.6-liter gasoline engine of the popular BMW Mini for the trihybrid and then tweaked it so it got a higher ethanol performance (Margolis, 2007).

Machado also launched a lean business plan, which relies heavily on existing parts (85% are off the shelf) and entirely on advance sales. Not a single Obvio is assembled until a firm order rolls in, which is meant to avoid costly stockpiling or prepaying suppliers (Margolis, 2007).

The Obvio apparently appealed to Steven Schneider, the CEO of a small, environmentally friendly California autodealer called ZAP (Zero Air Pollution), who was looking to import an economy size environmentally sound car to the United States (a US$1 billion deal with Daimler Chrysler had just fallen through), when the Obvio came along. Schneider put down US$700 million for a 20% stake in the Rio de Janeiro-based company, Obvio-Automotoveículos S.A., and the green machine from Brazil was on the roll (Margolis, 2007).

Measuring just 2.75 meters (85 cm shorter than the Mini Cooper) and weighing 700 kg, the Obvio makes other compact cars look bulky. Machado called on a veteran aeronautics engineer to rig the cabin with the same reinforced safety rings that gird small aircraft cockpits and has contracted Lotus Engineering to develop the Obvio's crash and pollution specs (Margolis, 2007).

Regarding performance and price the Obvio standard model can go from zero to 60 km/h in six seconds and still save some fuel. At US$14,000 it costs US$1,000 less than the Smart car and less than half the price of the Toyota Prius (a sportier version with a 250 hp engine planned for 2009 will fetch US$28,000) [Margolis, 2007].

Investments in the sugar industry : consolidation and mergers

The expansion of bioethanol production along with the general boom in Brazil's sugar production have attracted important investments. For instance, Bajaj Hindusthan, India's largest sugar producer set up a Brazilian subsidiary in 2006 and earmarked US$500 million for immediate investment in the country (*Seedling*, July 2007, pp. 20-24).

The Brazilian government also plays a key role in facilitating the consolidation of the industry. Much of government's support is channelled via the state oil company, Petrobras, which is developing the export infrastructure. Its latest project is a US$750-million bioethanol pipeline, stretching 800 miles from Brazil's interior to the Petrobras refinery in Paulinia and then to the port of São Sebastião. This pipeline will transport nearly half of Brazil's current ethanol production. Petrobras is also involved in securing long-term export markets for bioethanol. In 2005, it signed an agreement with Japan's state oil company Nippon Alcohol Hanbai, to create Brazil-Japan Ethanol, a joint-venture that expected to export 1.8 billion liters of bioethanol per year to Japan. In March 2007, as part of an US$8-billion partnership worked out between Japan and Brazil, Petrobras, Mitsui and Itochu agreed to set up a Brazilian joint venture that would supply ethanol to Japan for at least 15 years (*Seedling*, July 2007, pp. 20-24).

Brazil's sugar industrialists, also called sugar barons, are those who control most of the sugar and bioethanol production and trade. They are allied to transnational corporations; they have succeeded in attracting foreign investment and are building conglomerates with other local and multinational industrial financial groups. Some have even put their family businesses on to the Brazilian stock exchange (*Seedling*, July 2007, pp. 20-24).

Also between 2000 and 2005, there have been a lot of mergers and acquisitions (37) to expand production and export of sugar and bioethanol, i.e. many small firms and mills have been purchased by Brazilian sugar industrialists or barons. The result has been a few conglomerates, two of the most important being Crystalsev and Ometto conglomerates (*Seedling*, July 2007, pp. 20-24).

The Crystalsev conglomerate involves Brazil's Biagi and Junqueira families that are the major shareholders in Brazil's second biggest sugar and ethanol group, Vale do Rosário. Both families bought up the majority shareholders to counter buy-out from Cosan and Bunge. Thereafter they launched a merger process with another major Brazilian bioethanol producer, Santa Elisa, also controlled by the Biagi family. The merger of Vale do Rosário and Santa Elisa was completed in October 2007 and the new company Santelisa Vale will crush some 20 million tons of cane per year.

Santelisa Vale is the main shareholder of Crystalsev, which aims at becoming a completely integrated producer and trader. Crystalsev is also strengthening its ties with foreign corporations, Cargill in particular.

In June 2006, Cargill purchased Maurilio Biagi Filho's 63% share of the Cevasa bioethanol plant in São Paulo, which brought it within the Crystalsev frame. The Cevasa plant, with a capacity to crush 4 million tons per year of sugar-cane and to produce around 350 million liters of bioethanol, will ship hydrated ethanol from the TEAS ethanol terminal in Santos (a joint venture between Crystalsev, Cargill and two other major Brazilian ethanol exporters) to Cargill and Crystalsev's joint venture ethanol plant in El Salvador. This plant is also owned by the Compañía Azucarera Salvadoreña, and it is there where bioethanol is dehydrated and shipped on to the United States (the plant capacity is 60 million gallons a year). Bioethanol is admitted in the United States duty-free under the Caribbean Basin Initiative, a preferential trade agreement to which El Salvador is party. This Central American country, which exported 45 million gallons of bioethanol to the United States in 2006, is one of the four countries that receive technological assistance in biofuel production under the bilateral agreement between Brazil and the United States. Gasohol de El Salvador - a company of the Grupo Liza - is operating a plant having a capacity of 50 million gallons a year.

Cargill was not Crystalsev's only foreign partner. In 2006, Santa Elisa also formed a US$300-million joint venture with the international trading company Global Foods Holdings (United States), and one of the world's largest private equity firms, the Carlyle Group. The joint venture, called Companhia Nacional de Açucar e Álcool (CNAA), intended to have at least four new sugar mills in operation, with the capacity to crush 20 million tons of sugar-cane per year, by 2008. This would make CNAA one of Brazil's top three sugar producers. The medium-term objective was to expand into the cane-growing areas of the Centre-South of the country, with Crystalsev handling domestic distribution and Global Holdings organizing international trade (*Seedling*, July 2007, pp. 20-24).

Regarding the Ometto conglomerate, it controls Cosan, Brazil's largest sugar producer. In 2005-2006 financial year, Cosan milled nearly 28 million tons of sugar-cane and sold over 1 billion liters of ethanol. To become a transnational corporation, in 1999 Cosan sold 10% of its main port operations to Tate & Lyle – a global giant sugar corporation. Then it set up a joint venture in 2002 with major French sugar companies, Sucden and Tereos, which both have a large presence in Brazil's bioethanol and sugar trade, and in 2005 established a partnership with the Kuok Group from Hong Kong. Tereos, Sucden and Kuok became major shareholders in Cosan, although Ometto retains a majority stake.

Kuok, a leading player in the palm-oil-derived biodiesel industry, also has an important stake in Cosan, through its agro-industrial conglomerate, the Singapore-based Kerry International. More foreign investment flew into the company in November 2005, when Cosan made an initial public offering on the Brazilian stock exchange, ceding a further 27% of its shares to foreign stakeholders.

Ometto also controls São Martinho, which used to be Brazil's second-biggest sugar producer (behind Cosan) and the operator of Brazil's largest sugar mill (7 million tons per year). By early 2007, São Martinho followed Cosan's lead and launched an initial public offering on the Brazilian stock exchange, bringing in US$176 million in capital and a substantial foreign ownership presence. In March 2007, it signed an agreement with Mitsubishi Corporation, giving the Japanese firm 10% ownership of its Usina Boa Vista – a plant with a crushing capacity of 3 million tons per year. That factory was financed with US$250 million from Brazil's National Economic and Social Development Bank (BNDES). The agreement also involved a 30-year contract under which the plant will sell 30% of its production to Mitsubishi for export to Japan. About the same time, São Martinho joined Cosan to purchase the Santa Luiza ethanol plant in São Paulo, with a capacity to crush 1.8 million tons of sugar-cane per year.

Another important element of the Ometto conglomerate is its close connection with Votorantim, one of Brazil's largest family-run industrial groups, controlled by Brazilian billionaire Antonio Ermirio de Moraes. Both companies set up a partnership in sugar-cane breeding between Cosan and Votorantim's subsidiaries, CanaVialis – the world's largest sugar-cane breeding company, and Allelyx, the most important sugar-cane biotechnology company in Brazil. Thereafter, in May 2007, Votorantim and Monsanto formally announced their partnership to develop genetically modified sugar-cane, stating that they would have GM Roundup ready varieties (i.e. tolerant to the herbicide Roundup or glyphosate) for commercial introduction in Brazil by 2009. Votorantim also owned 28% of Aracruz Celulose, the largest hardwood producer in the world and Brazil's biggest eucalyptus company (*Seedling*, July 2007, pp. 20-24).

Louis Dreyfus was in 2007-2008 Brazil's second-biggest sugar producer and trader. It first purchased the Cresciumal refinery in São Paulo in 2000, and subsequently took control of Coinbra, which operates oilseed crushing facilities and oil refineries, and of five mills owned by Tavares de Melo.

Since its implantation in Brazil in 2000 and its purchase in 2003 of the biggest French sugar company, Beghin-Say, Tereos has become the biggest French sugar-producing group and the world's fourth biggest. In 2006, its annual turnover was estimated at €2 billion (in 2005, it reached €1.757 billion, while the net profit was €61.3 million). In France, Tereos gathered 14,000 farmers in 13 cooperatives. It is the fifth largest cooperative in France in terms of annual turnover. Worldwide, it is at the fourth rank, behind the German Südzucker, British Sugar and Brazilian Cosan. In 2007, Tereos' output was 4.3 million tons of sugar and 1,300 million liters of ethanol.

In November 2005, when Cosan was listed at São Paulo's stock exchange, Tereos, which owned the sugar factories of Guarani (belonging to Beghin-Say), was thinking of introducing 25% of its capital on the stock exchange. It indeed needed US$200 million in 2008 for completing the construction of another complex of factories. Açucar Guarani, now a 63% subsidiary of Tereos, had an annual turnover (2006) of €300 million. It milled 8.2 million tons of sugar-cane, compared with 3 million tons in 2002.

Tereos' presence in Brazil is a key advantage for agrofuel production; Tereos (in 2006) was the world's fifth largest producer of ethanol. It has recruited the former president of Brazil's largest distributor of ethanol, Jacyr Costa Filho. Tereos' ambition is to become a leader on several continents or regions and in cane, beet and wheat. It has settled in La Réunion, in Mozambique, could not acquire the African sugar leader, Illovo, purchased by British Sugar, but intended to be present in 2007 in Eastern Europe.

For Tereos, Europe remains an anchor point, the advantage being the governmental plans to develop agrofuel production as well as the protection offered by environmental regulations. Tereos is a key player in the development of agrofuels in France, where "it owns two distilleries – one for ethanol fermented from beet sugar and the other for ethanol from wheat starch. This activity could lead to the creation of a subsidiary - Tereos énergie - and thereafter introduced on the stock exchange, an approach followed by Südzucker.

Foreign investments

In the United States, the realistic opinion of biofuel experts (e.g. Charles Washburn, or John F. Wasik) has not prevented Wall Street stock exchange to remain optimistic about bioethanol production (Gulf ethanol that had an estimated market value of about US$24 million, had its shares rise 40%;

Archer Daniels Midland, which is the biggest bioethanol producer in the United States, had its shares rise 14%). Brazil is attracting more international investments than any other country. In 2006 alone, over US$9 billion were invested in Brazil's ethanol industry, with US$2 billion devoted to the construction of new plants (*Seedling*, July 2007, pp. 20-24).

Arnaldo Vieira de Carvalho, an energy specialist at the Inter-American Development Bank in Washington, D.C., considers current investment in bioethanol as a way of building up a better stake today for whatever the most impressive biofuel technology turns out to be tomorrow. "If you now put your money in distilleries, in five years you have made your money, and then you put your investment in the technology that is coming" (Marris, 2006).

But Brazilian officials and business executives stated that the ethanol industry would develop even faster if the United States did not levy a tax of US-cent54 a gallon, or about US-cent14 a liter on all imports of Brazilian cane sugar-derived ethanol. They complained that US restrictions have inhibited foreign investment, particularly by Americans. As a result, ethanol development has been led by Brazilian companies with limited capital. But with oil prices soaring, the four international giants that control much of the world's agribusiness - Archer Daniels Midland, Bunge and Born, Cargill and Louis Dreyfus - have shown increasing interest (Rohter, 2006).

In March 2007, during his journey to a few countries of Latin America, the US president visited Brazil (8 March 2007) and signed an agreement with president Luiz Inácio Lula da Silva, who is convinced that agrofuels are a springboard for development. Brazilians are of the opinion that an agreement with the United States on biofuel technologies and production is useful; their scientists and officials consider that negotiations among Brazilians, Americans and Europeans should focus on common research, rather than on trade barriers. Brazil privileges a geopolitical approach, while at the same time considering that an agreement with the United States should bring international visibility and credibility (Gasnier, 2006).

Brazilians are willing to share technology with those interested in following their country's example. Eduardo Pereira de Carvalho, president of the São Paulo's Sugar-Cane Manufacturers' Union, stated in 2006: "We are not interested in becoming the Saudi Arabia of ethanol. It is not our strategy because it does not produce results. As a large producer and user, I need to have other big buyers and sellers in the international market if ethanol is to become a commodity, which is our real goal". In fact, the agreement between the United States and Brazil, and its extension to other bioethanol producers and users, particularly in the Americas, is a step towards the creation of a world market for bioethanol, which would add value to the quality of a Brazilian product aimed at supplying the whole world (Rohter, 2006).

The Inter-American Development Bank (IDB) is working closely with the Inter-American Ethanol Commission to develop the global market for ethanol. In Brazil, the IDB is "focusing on leveraging private sector investments to expand production capacity". Its Private Sector Department was structuring senior debt financing for three Brazilian ethanol production projects with a total cost of US$570 million and loans for five biofuel projects worth around US$2 billion were in the pipeline (*Seedling*, July 2007, pp. 20-24).

The following investment funds are playing an important role in the expansion of Brazil's ethanol industry.

Infinity Bioenergy, a Bermuda-based fund listed on the London stock exchange, was formed by about 50 investors in 2006, one of them being the American fund Kidd & Company. The fund has spent US$400 million purchasing controlling interests in these plants with a first milling capacity of 3.5 million tons of sugar-cane, and is investing in the construction of two new plants in the States of Espirito Santo and Bahia. Infinity Bioenergy also announced that it was merging with the Evergreen fund, another British investment fund targeting Brazilian ethanol industry with a majority interest in the Alcana ethanol plant in Nanuque. Infinity Bioenergy planned to export at least part of this production to the United States, and was therefore investing US$20 million in a dehydration plant in the Caribbean that would provide duty-free access to the US market (*Seedling*, July 2007, pp. 20-24).

Bioenergy Development Fund, launched in early 2007 in France's third biggest bank, Société Générale, is incorporated in the Cayman Islands. After raising US$200 million in its first month, the fund aimed at raising a total of US$1 billion in 2007. Société Générale is also involved in investments in US ethanol plants (*Seedling*, July 2007, pp. 20-24).

Brazilian Renewable Energy Company Ltd (Brenco) is financed by several well known investors, such as Sun Microsystems' founder, Vinod Khosla: its goal over the next ten years was to reach an annual output of 3.8 billion liters of bioethanol, according to market sources. Brenco was incorporated in Bermuda, but had its headquarters in São Paulo.

Clean Energy Brazil, established by Numès, an English investment bank, includes partners such as Czarnikow Sugar, one of the world's largest sugar brokers and the broker for approximately 30% of the Brazilian sugar/ethanol market and Agrop, owned by Brazil's Junqueira sugar family. The fund operates on the London stock exchange, and raised US$185 million in its initial public offering (IPO). In 2007, its first acquisition was that of a 49% stake of the Usaciga sugar group (*Seedling*, July 2007, pp. 20-24).

Environmental impact of the expansion of bioethanol production

It has been stated that the increasing investments in sugar and bioethanol production would push that production into new areas, particularly on the lands that have long been used for cattle pastures. Quoted by *Seedling* (July 2007, pp. 20-24), Eduardo Pereira de Carvalho, president of São Paulo's Sugar-Cane Manufacturers' Union, predicted that as much as a third of Brazil's current pasture land would be converted to sugar-cane production in the near future.

In 2005, the federal government launched the National Agroenergy Plan, which is coordinated by the ministry of agriculture, livestock and food supply (Mapa) and the Brazilian Agricultural Research Corporation (EMBRAPA).

In 2007-2008, EMBRAPA estimated that 90 million hectares were available for agricultural expansion in Brazil, out of 852 million hectares. The sugar-cane area was 7.8 million hectares, i.e. less than 1% of the national territory. Another 30 million hectares occupied by underutilized pastures could be released for other farming activities in the future without any impact on meat and milk production, a fact already made apparent in the State of São Paulo. Thus agrofuels would not necessarily compete with food crops in the short and medium-term in Brazil (Betinardi Strapasson et al., 2007).

Although large areas were available for the expansion of sugar and bioethanol production in Brazil, in the case of São Paulo State (which produces about 60% of total bioethanol output) and in some regions of the States of Paraná, Minas Gerais and Mato Grosso do Sul, the expansion of sugar-cane raises problems relating to intensive monoculture. These problems were already noticed in the States of Pernambuco, Alagoas and Paraíba (Betinardi Strapasson et al., 2007).

Brazilian experts consider that sugar-cane cultivation should not be extended to already saturated regions such as those of Brazil's centre-south, northeast, in particular in the States of São Paulo, Alagoas and Pernambuco, in order to mitigate agronomic and environmental issues, as well as the economic vulnerability of these States if they were confronted with an eventual crisis in the cane plantations. It is true that most of the new investments in sugar and bioethanol production are made in the State of São Paulo, but they are increasing in Goiás and Minas Gerais. Experts consider that they should be oriented towards the States of Maranhão, Piaui and Tocantins (Betinardi Strapasson et al., 2007).

Expansion of cane fields into some of the millions of hectares available would be more or less carbon-neutral according to Robert Boddey, a soil chemist at EMBRAPA: "for degraded pastures, which are slowly losing carbon, it is not such a bad change. And almost 70% of the cerrados (savannas of which Brazil has some 200 million hectares) has already been cleared. On the other hand, because it needs a dry season, sugar-cane would not be a good crop to move into cleared rainforest areas. In this respect, sugar-cane is more environmentally friendly than oil-palm (Marris, 2006).

In 2006, a paper by a group at Washington State University in Richland claimed that Brazil's ethanol was bad for the environment. The conclusion was disputed and the industry seemed to become more environment friendly as it strived for efficiency gains. As Christopher Flavin, of the World Watch Institute, Washington, D.C., pointed out, expansion will generally mean that a higher proportion of the industry will be using newer and cleaner technology (Marris, 2006).

Recycling of wastes of sugar-cane cultivation and alcohol production

Brazil indeed has made remarkable efforts to process and re-use the wastes of sugar-cane harvest and alcohol production.

Sugar-cane stubble accounts for one third of the overall sugar-cane harvested. The stubble is either burnt during harvesting or left behind as soil cover. Another third is sugar-cane juice, used for sugar production and sugar fermentation into alcohol. And the final third is a solid residue from cane crushing or bagasse. After the liquid sugar-containing juice is used to produce sugar or ethanol, the liquid effluent is called stillage.

For many years the stillage was improperly disposed of in the soil and nearby watercourses. Because of its high biochemical oxygen demand (BOD), stillage caused dramatic reductions of the aerobic species, as well as eutrophication due to the excess of nutrients. At present, however, stillage is applied as organic fertilizer to areas where sugar-cane has been harvested using pumps or canals to deliver the fertilizer. Stillage is rich in macro and micronutrients, particularly potash (K_2O). Since potassium deficiency is common in most sugar-cane plantation soils, the use of stillage is beneficial. Stillage can also be fermented in bioreactors that produce methane (biogas) through anaerobic digestion, although nutrient concentration is not significantly reduced. Thus, it would still be possible to use the wastes for fertilizing purposes (Betinardi Strapasson et al., 2007).

The greatest challenge to the advancement of ethanol production technology is the energy requirements of stillage dehydration, which can be met using the energy sources in the production process itself, such as sugar-cane bagasse.

Bagasse indeed is presently used to produce thermal, mechanical and/or electric energy necessary to make sugar and alcohol, and to maintain other plant activities. Plants are progressively becoming self-sufficient and in many cases are exporting electric power to the grid. According to data from the National Energy Balance, sugar-cane products accounted for 15.4% of the Brazilian energy mix in terms of primary energy production in 2005. Sugar-cane bagasse accounted for 1.8% of the electric power supply in the country, including the electricity consumed by sugar mills, an average 80% of the total amount generated.

A Sugarcane Technology Center study carried out in 2005 in partnership with the United Nations Development Programme and coordinated by the ministry of science and technology concluded that approximately 50% of the sugar-cane-stubble left on the ground after the harvest could be used to produce additional energy, without compromising sugar-cane production. The remaining straw would be sufficient to improve and protect the soil. The challenge is to find viable solutions to transport the low density/high volume stubble from the fields to the mill (Betinardi Strapasson et al., 2007).

Reduction of greenhouse-effect gas emissions and air pollution

Regarding the impact of ethanol consumption on the reduction of greenhouse-effect gas emissions (CO_2), the analysis made by Isaias de Carvalho Macedo at the University of Campinas concluded that a ton of cane used as ethanol fuel represented net avoided emissions equivalent to 220.5 kg of CO_2 when compared with petroleum with the same energy content. The Brazilian team extrapolated that ethanol use in Brazil reduced greenhouse-effect gas emissions by the equivalent of 25.8 million tons of CO_2 equivalent a year. Brazil's total carbon dioxide emissions from fossil fuels was 92 million tons a year in 2006, according to the US Department of Energy. The improvement is thus substantial (Marris, 2006).

By preventing the emission of additional greenhouse-effect gases, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), as related to a baseline (trend) scenario, it is possible, according to the Kyoto Protocol of the United Nations Convention on Climate Change, to obtain a certificate equivalent to the emissions avoided by the project, also called Certified Emissions Reduction (CER), or sell such credits in the international carbon market, either directly or in a stock exchange or futures markets.

In Brazil, most prospects approved by the International Commission on Global Climate Change are related to the bioenergy area and to the use of biogas from urban solid wastes decomposition in landfills, which has an enormous growth potential. Among the agroenergy projects special mention should be made of bagasse co-generation projects, which represented 32% of all approved projects in 2005. Those projects usually request credits for emissions avoided through the non-utilization of other energy sources to meet the demands of an industrial plant, such as, for instance, diesel, fuel oil, and electricity from the electric grid, a part of which comes from fossil energy sources (Betinardi Strapasson et al., 2007).

Although sugar-cane bagasse co-generation is one of the main types of projects submitted to the Interministerial Commission, the ground has barely been scratched if one considers the high number of registered sugar and alcohol plants in the country. Co-generation indeed is a significant contribution of the sugar industry to the struggle against the escalation of the greenhouse-effect and consequently against climate change (Betinardi Strapasson et al., 2007).

Polluting gas emissions of ethanol-fuelled engines are lower than those of gasoline-fuelled motors. Some countries still add tetra-ethyl lead to gasoline to enhance performance, but that additive is unnecessary when anhydrous alcohol/gasoline blends are used. In 1992, Brazil was the first country in the world to completely stop adding lead to gasoline, although most of the petroleum refined in the country had been unleaded since 1989. Furthermore, with the ethanol-gasoline blend there is also no need to use other additives like MTBE (methyl tertiary butyl ether) and ETBE (ethyl tertiary butyl ether), thus avoiding the environmental contamination by these compounds (Betinardi Strapasson et al., 2007).

Compared with gasoline, ethanol consumption produces less carbon monoxide, sulphur dioxide and particulate emissions. According to studies carried out in Australia with a 10% ethanol/gasoline blend the following emission reductions were: 32% for CO, 12% for total hydrocarbons (THC) and 7% for CO_2. Nitrogen oxide emissions were similar for both fuels. In the case of aldehydes, ethanol emissions are slightly higher than those of gasoline, but not higher than those of diesel. Those emissions can be easily prevented using automobile catalizers. Brazil made catalizers mandatory in new vehicles in 1992. Finally, the use of 10%-15% ethanol/diesel blends leads to significant reductions of most polluting gases, particularly sulphur emissions, compared with emissions from pure diesel fuel (Betinardi Strapasson et al., 2007).

Ethanol is biodegradable, miscible in water, hygroscopic and volatile when exposed to air. Consequently, the environmental impact of eventual ethanol leaks or spills during storage and transportation, whether land or maritime, is much lower than that of oil and petroleum products. Exception is made of leaks or spills of gasoline/ethanol blends into the ground, especially at filling stations, in which the "co-solvency effect" increases ground water-table contamination by the fuel and migration of the more dangerous and soluble gasoline compounds, such as benzene, toluene, ethylbenzene and xylene (Betinardi Strapasson et al., 2007).

Conclusions

Although two of the main environmental problems associated with ethanol production have been solved by using stillage and bagasse at different stages of the production chain itself, there remain such problems as pre-harvest burning of the crop and sugar-cane encroachment in saturated areas. Sugar-cane burning could greatly diminish as the State of São Paulo progressively prohibits it and since the State accounts for the largest share of sugar-cane production in the country. Other States should follow suit.

On the other hand, eliminating sugar-cane burning has an unfavourable, albeit indirect, effect on employment rates. Sugar-cane harvest is mechanized to the extent of 55%; while a worker could harvest 10 tons of cane in eight hours, a machine could harvest 700 tons in 24 hours. The whole sector was employing 1 million workers, half of them being involved in the harvesting process (Gasnier, 2008b). Although sugar-cane harvesting is frequently temporary, it is often the only work opportunity open to a large number of rural workers, most of whom are unskilled. There are simply no other jobs that pay as much in the rural areas. It would be therefore necessary that the enforcement of the environmental control measures be accompanied by upgrading the skills of workers and finding jobs for them in other activities (Betinardi Strapasson et al., 2007).

Sugar-cane cultivation should not expand into saturated areas such as some centre-south and northeast regions, particularly in the States of São Paulo, Alagoas and Pernambuco, in order to prevent worsening of agronomical and environmental problems and to reduce the economic vulnerability to possible agricultural crises in the sugar-cane plantations. Although most new investments are being made precisely in the State of São Paulo, the number of sugar-cane production projects is also increasing in other States, particularly Goiás and Minas Gerais. New sugar-cane development projects should be planned in the States of Maranhão, Piaui and Tocantins (Betinardi Strapasson et al., 2007).

Ethanol prospects are promising in both domestic and international markets. In Brazil, not only has it proven to be an important alternative to petroleum, but it also spurred the alcohol chemical industry; beginning during the 1970s and 1980s and producing at that time dichloro-ethane, acetic acid, acetaldehyde, PVC and ethyl acetate, in the 1990s Brazil manufactured approximately 30 products, with special emphasis on dichloro-ethylene, polyethylene, ethylbenzene and PVC.

Energetic efficiency of bioethanol production

The carbon from ethanol put into the atmosphere is carbon that was just a couple of years ago in the air before the sugar-cane assimilated it through photosynthesis. There are thus, in principle, no net emissions of CO_2. However, growing sugar-cane, harvesting it, fermenting the sugar and distilling the alcohol and then distributing it is a complex business. It uses inputs – fuel for harvesters, nitrogen fertilizers for the cane – that themselves require energy from elsewhere. It has also potential damaging effects, such as soil erosion and the emission of nitrous oxide, a greenhouse gas, from farmland. Taking all this into account, is ethanol still a good deal as it seems? (Marris, 2006).

In 2004, Isaias de Carvalho Macedo at the University of Campinas carried out a study for the State of São Paulo that considered energy inputs such as fertilizer manufacture and agricultural machinery in the sugar-cane industry. He and his colleagues estimated that the sugar-cane industry cost was about 250,000 kilojoules per ton of cane. That ton of cane in turn yielded about 2 million kilojoules in ethanol and surplus electricity supplied by burning bagasse. That is an eight-fold return (Marris, 2006).

This is a lot better than ethanol-producers in the United States manage. Sugar-cane is a far more prolific plant than maize. What is more, sugar-cane needs less by way of inputs, and in the parts of Brazil where most of it is grown it needs no irrigation. It must only be ploughed up and replanted every five years; between times it can be cropped repeatedly and will simply grow back, although the yields drop a little with each harvest. For all these reasons, sugar-cane ethanol is also currently the cheapest ethanol produced worldwide. A liter cost about US-cent25 to make in 2006-2007. The commodity price for anhydrous ethanol (the kind mixed into gasohol) was about US-cent27 (2006). Because of this, a lot of money is pouring into the centre-west and centre-south region of Brazil (Riberão Prato), where sugar-cane grows best (Marris, 2006).

Sugar-cane yields are the highest in the world, thanks to optimal climatic conditions and to higher yielding varieties selected through conventional breeding (Brazil leads the research on sugar-cane genomics and possesses a very large germplasm bank) and more recently through genetic engineering. Yields are expected to increase in the future through better management and the use of new technologies, for the production of bioethanol and the recycling of all the wastes of sugar-cane harvest and processing. The current average production of 6,500 liters of bioethanol per hectare of sugar-cane will therefore increase.

It should be recalled that sugar-cane as a source of bioethanol, has a much higher energy efficiency than maize, wheat or sugar-beet, and even more when the bagasse – the main milling or crushing residue – is effectively used:

raw material	energy balance (output/input)
wheat	1.2
maize	1.2-1.8
(sugar-beet (European Union	1.9
(sugar-cane (Brazil	8.3

This efficiency is even greater when potential breeding and biotechnology advances are taken into account, including extracting energy from sugar-cane bagasse, taking better advantage of sugar-cane stubble, using more efficient energy-conversion equipment and processes, and ensuring more efficient use of industrial wastes (Betinardi Strapasson et al., 2007).

Prospects

The 50 new sugar mills that were being built in 2007 in the States of Goías, Minas Gerais, Mato Grosso do Sul, Paraná, Rio de Janeiro and São Paulo, were expected to crush 75.5 million tons of sugar-cane during the 2011-2012 harvest. In 2010, the daily production of bioethanol was predicted to reach 90 million liters, thus supplying the increasing number of flex-fuel cars that use at least 23% bioethanol in their gasoline.

It has been forecast that the growth of domestic market was limited: in the case of sugar, the increase in consumption was to be rather small, while in the case of bioethanol even though all flex-fuel vehicles were to use only alcohol, the rise in demand would not be sufficient to absorb all the available bioethanol. The latter will have to be exported and prices will decrease.

BRAZIL'S BIODIESEL PRODUCTION : OUTPUT, RESEARCH AND PROSPECTS

By 2007, Brazil's ministry of mines and energy estimated that hydroelectric power accounted for 14% of the energy produced in the country, while biomass represented another 27%. The successful implementation of the National Alcohol Programme has resulted in the fact that ethanol accounted for 40% of the fuel consumption of Otto cycle vehicles. In addition, many sugar and alcohol plants, having achieved energy self-sufficiency, are selling increasing quantities of surplus electric power produced through co-generation from burning sugar-cane bagasse (Rosa e Abreu et al., 2007). See also Hazell and Pachauri (2006).

However, dependency on diesel oil imports was still a problem to be solved. In 2005, more than 38 million m3 were consumed or 57.7% of all liquid fuels. Biodiesel has never been an economically attractive proposition because the market price of vegetable oils has been higher than that of mineral diesel. But the Brazilian government has supported the production of biodiesel as a means of social inclusion, generating jobs and income opportunities for the poorest among the rural population, especially smallholders and family farmers in the semi-arid Northeast. Furthermore, biodiesel would enable the country to obtain international funds by applying the Kyoto Protocol mechanisms, such as the Clean Development and Emissions Trading schemes (Rosa e Abreu et al., 2007).

In December 2004, the government launched the National Programme for the Production and Use of Biodiesel (PNPB).

In fact, Brazil has been carrying out research on biodiesel since the 1970s with special focus on African palm oil. The use of vegetable oils for producing energy was first proposed in 1975 and led to the Plan for the Production of Vegetable Oils for Energy Purposes (Pró-Oleó), whose main objective was to produce vegetable oil surpluses that would make oil production costs competitive with those of petroleum. The proposal was to mix 30% vegetable oil with fossil diesel and eventually replace the latter completely (Rosa e Abreu et al., 2007).

In 1980, Brazil became the first country to obtain a patent for a biodiesel production process. In 1983, confronted with the spiraling oil prices, the Brazilian government decided to implement the Vegetable Oil Project (Oveg Project) with a view to testing the use of pure biodiesel and various biodiesel/fossil diesel mixtures. Thereafter, in December 2004, the PNPB was launched in order to foster biodiesel production and use in the country in a technically and economically sustainable manner. The government also created the Brazilian Biodiesel Technology Network (RBTB), constituted of research organizations in 23 States of the Brazilian federation (Rosa e Abreu et al., 2007).

The regions involved in the production of biodiesel are the following: North (use of local species such as oil-palm, babassu; generation of electric power in remote and inaccessible areas); Northeast (castor bean production under family agriculture conditions); Centre-West (local use of soybeans, decrease of diesel transportation freights to coastal cities); South and South-East (improving air quality in major cities by reducing diesel emissions).

Biodiesel blends and financial support

Law no. 11.097 of 13 January 2005 established a minimum legal and mandatory percentage (5%) of biodiesel blended with fossil diesel throughout the national territory. The period for achieving the biodiesel blend would be 2013, but a 2% mixture was required in 2008. This represented an annual demand for approximately 800 million liters of biodiesel (while actual production amounted to 200 million liters in 2006). It was estimated that close to 1.5 million hectares would be required to produce enough raw material to add 2% biodiesel to the fossil diesel consumed in the country, i.e. the equivalent of 1% of the farmable land in Brazil (150 million hectares) [Rosa e Abreu, et al., 2007].

The Financial Support Programme for Biodiesel Investments finances up to 90% of loan-worthy investments for projects with the Social Fuel Seal and up to 80% for the rest. Loans can be taken for any biodiesel production phase, including storage, logistics and by-product processing. Banco do Brasil's BB Biodiesel offers credit lines for both agricultural and industrial production (BNDES Biodiesel, Pronaf Agroindustry, Prodecoop, and Agroindustrial Credit for the purchase of raw material). In order to minimize operational risks, the banks usually require a commercialization guarantee; the farmer should only ask for a loan to invest in a given oleaginous crop if he already has a buyer for his production; likewise, industries must also sign contracts with the fuel-distributors responsible for mixing and distributing biodiesel (Rosa e Abreu et al., 2007).

Biodiesel output

In Brazil, most of the biodiesel, including biodiesel for self-consumption, is produced through transesterification of vegetable oils, animal fats or fatty acids from vegetable oil refining operations. There are, however, some cases of production by esterification (such as Agropalma, which uses the wastes from the African palm-oil refining process) and cracking can be used in isolated communities. Despite the interest in developing an ethylic pathway, the transesterification process can also use methanol. The methylic pathway facilitates the reaction when castor oil is used as raw material, and it is therefore much more likely to be used in the Northeast and semi-arid regions (Rosa e Abreu et al., 2007).

While in the central-southern region of the country the abundance of ethanol will promote the ethylic pathway of transformation of soybean, sunflower and white radish (Raphanus sativus) oils into diesel, methanol may be preferably used in industrial plants using bovine suet.

Biodiesel production raises the challenge of taking advantage of the potential (agricultural, industrial and economic) of each region of the country.

North region. Although this region is mainly devoted to both intensive (rice, maize and cassava) and subsistence (mostly beans and cassava) agriculture, its greatest potential lies in the exploitation of forests, due to the predominant humid equatorial climate. Palm trees are the best raw material for biodiesel production.

In addition to a great diversity of native palm trees, the Brazilian Amazon has the greatest potential for African oil-palm plantations in the world, with an area estimated at 70 million hectares. The production potential would be equivalent to 350 million m^3 of oil per year (Rosa e Abreu et al., 2007).

There are around 40,000 communities in the region and for some of them biodiesel can be a local energy alternative. Since it is not connected to the Brazilian Integrated Electric Grid, the region depends on diesel-fueled stationary generators. The latter are so far from oil refineries that the risk of running out of fuel is an ever-present threat. Henceforth, palm oil produced locally, is an extremely relevant alternative (Rosa e Abreu et al., 2007).

Palm trees can be planted over the existing deforested areas, particularly in the State of Pará, which already accounts for more than 80% of the current African palm-oil production in the country. The oil yield varies between 4 and 6 tons per hectare. Another possibility is to exploit the native varieties under forestry management conditions; these activities are labour intensive and would require large numbers of smallholders/ family farmers (Rosa e Abreu et al., 2007).

Northeast region. It accounts for approximately 15% of the diesel oil consumed in the country. Researchers are focusing on castor bean plantations and production projects. The Northeast region is subdivided into three subregions: Zona da Mata, Semi-arid and Sertão. There are also sizeable areas of cerrados (savannas) and transition areas with the Amazon region where the humid equatorial climate prevails.

The Zona da Mata has a long history of commercial agriculture based on sugar-cane monoculture and accounts for 15% of sugar-cane production. The farmed area is approximately one million hectares. The potential area for oleaginous crops has been estimated at 200,000 hectares with an annual production of up to 150,000 tons of oil, depending on the option selected. Although sunflower, peanuts and sesame have been considered, there are few experimental plantations, especially operations aimed at integrating the sugar and ethanol production and biodiesel raw material production (Rosa e Abreu et al., 2007).

In the Semi-arid subregion, castor beans have become the leading crop during the initial phase of the PNPB and the main oleaginous crop option for the Northeast. Castor beans are attractive because in addition to producing oil, they can be planted in association with other crops, such as beans, peanuts and maize. There are more than 3 million hectares of land where castor beans could be farmed under day-farming conditions, with a potential production of 1.2 tons of castor beans per hectare (47% oil content). Most of the current production comes from the State of Bahia, where the crop occupies 130,000 hectares and annual production amounts to 90,000 tons of beans (70% of national output) [Rosa e Abreu et al., 2007].

For instance, in the agrovillage Canudos, a collective farm located at Ceara Mirim, 100 km from Natal – the capital of the State of Rio Grande do Norte, next to cassava, papaya and banana trees, the farmers have planted Jatropha curcas (locally called "pinhao manso") which grows in this semi-arid region and whose fruits contain 38% of a non-edible oil that can be converted into biodiesel. Even on sandy soils, this shrub produces 3 tons of fruits per hectare and can be harvested twice a year. Petrobras supplied the seeds to Canudos cooperative, which planted 1,200 trees of *J. curcas* (Gasnier, 2006).

Petrobras also supplied castor beans to 142 farmer households in another rural community near Upanema (250 km from Natal), called Palheiros III. That gave birth to a plantation of 300 hectares easy to maintain; during a useful two-year production period, a tree can be harvested six times. A great advantage is to add value to land that otherwise would be abandoned, and to bring another source of income to the small and poor farmers. Petrobras is therefore planning to build a big factory for biodiesel production in Rio Grande do Norte (Gasnier, 2006).

In 2006-2007, the industrialization of biodiesel production from castor bean oil was still at the experimental stage. Petrobras had already invested US$8 million into the refining plant of Guamaré. Trials had been initiated in July 2006 at Guamaré and were to last 18 months, a test on 100 tons of oilseeds was to be carried out every month, with a view to producing a reliable and cheap biodiesel (Gasnier, 2006).

In the cerrados, particularly in Western Bahia and the southern areas of the States of Maranhão and Piaui, as well as in the transition zones with the Amazon, palm trees such as the babassu (Orbignia phalerata) can become an important option. In Maranhão, babassu palms grow over 18 million hectares. Although babassu oil is an excellent source of biodiesel, there are some restrictions, such as the extraction costs; oil represents only 4% to 5% of the weight of the fruit which is surrounded by a very hard shell (Rosa e Abreu et al., 2007).

Centre-South. Soybeans and sugar-cane are the main crops in the States of Rio Grande do Sul and Paraná, and in the States of Paraná and Minas Gerais, respectively. Both are extensively farmed in the Centre-West. The region has also considerable potential for castor beans, peanuts and sunflower, the latter two, already being planted in this region. Experiments in the State of Mato Grosso and research at the Instituto Agronómico de Campinas (IAC) have shown that the so-called castor bean dwarf varieties had high yields (up to 4 tons of beans per hectare) and could be mechanically harvested (Rosa e Abreu et al., 2007).

In the short term, bovine suet (with the lowest costs) and soybeans (largest available supply) are the main options for biodiesel production. However, bovine suet, a by-product of meatpacking plants, the cheapest raw material presently, has a limited supply and its prices could increase as the demand rises. There are also technical and economic advantages in coupling transesterification units to sugar and alcohol plants. Another important consideration is that soybean, sunflower and peanut oils have an already developed market, and biodiesel production will thus complete with the option of selling these oils in both domestic and foreign foods markets (Rosa e Abreu et al., 2007).

Conclusions

Through the National Programme for the Production and Use of Biodiesel, Brazil is trying to obtain an alternative fuel to petroleum diesel in the energy mix, that can play an equivalent role to ethanol with regard to gasoline. One of the priorities of the biodiesel programme is to create the conditions for the competitive insertion of family agriculture and smallholders into the production chain. In so doing, less developed regions, such as the Semi-arid, could find a development process that may reverse the historical poverty patterns. But such an objective, although indisputably legitimate, is thwarted by the availability of farmable lands in other regions of the country that offer better conditions for intensive agriculture, leading to a lower cost of production of biodiesel. Consequently, defining a tax pattern bestowing tax benefits for the biodiesel produced from smallholdings in the poorer States, could lead to low economic efficiency (Rosa e Abreu et al., 2007).

There is nevertheless space for concrete actions to achieve higher levels of diesel substitution in specific market segments. This is the case of stationary generators in remote regions, consumption in rural areas that are far from fossil fuel-refining and distribution centres, and some types of big consumers, such as freight transport companies. To sum up, biodiesel production aims at both drastically reducing dependence on fossil diesel and contributing to rural development (Rosa e Abreu et al., 2007).

AGROFUEL PRODUCTION IN LATIN AMERICA AND THE CARIBBEAN

The Brazilian government has signed a US$100 million agreement with its Ecuadorian counterpart to set up two ethanol plants in **Ecuador** and to introduce high-yielding varieties of Brazilian sugar-cane. Ecuador had two advantages: the 10,000-tons-per-year quota it has for the US market; and the unlimited access it has been given to the European Union (EU) market as part of a diversification programme to encourage farmers to stop cultivating coca and other illegal crops. Similar deals have been concluded with Caribbean countries that have trade access to the United States under the **Caribbean Basin Initiative (CBI)**. Free-trade agreements with Central American and Caribbean countries enable the latter to export ethanol to the US market at advantageous prices. In addition, the agreement signed between Brazil and the United States in March 2007 included technology and know-how transfer to these countries in order to help them develop or rebuild their sugar industry and ethanol production. For instance, in the Dominican Republic, a new start for the sugar industry also included trials with sugar-cane, sweet sorghum, jatropha and castor bean to produce bioethanol and biodiesel.

However several Central American and Caribbean countries are just importing ethanol from Brazil, dehydrate it and reexport it to the United States, where it is blended with gasoline. By so doing, they do not pay the US-cent54-per-gallon tax, which applies to those countries that have no free-trade agreement with the United States, such as Brazil. This country should therefore pay the US-cent54-per-gallon tax but not if its bioethanol were exported through El Salvador or Jamaica.

Importing bioethanol is advantageous for the East Coast of the United States, as it is less costly than transporting it from Iowa or Mid-Western States to supply the East Coast.

Thus, in 2006, 206 million gallons of bioethanol have been imported from Central America and the Caribbean, which was less than the 268 million gallons authorized (i.e. less than 7% of the US consumption).

Big agro-industrial corporations play a key role in this trade. For instance, Cargill, which owns a bioethanol plant in El Salvador, had imported 107.9 million gallons of bioethanol, mainly from Brazil, between 2000 and mid-2007. Vitol imported 105.3 million gallons from El Salvador; Northville Industries, 84.1 million gallons from Jamaica; and ED&F Man, 68 million gallons also from Jamaica.

Although there are some complaints in the United States against importing bioethanol from Central American and Caribbean countries without imposing the federal tax, these countries can benefit even more if they become big producers and exporters of bioethanol instead of just dehydrating and reexporting bioethanol. They will benefit from tax exemption in the United States, if 50% of their bioethanol is produced from local raw material.

Guatemala and Nicaragua are the only Central American countries that produce bioethanol from their own sugar industry, and most of their production is exported to Europe. One should recall that further to the end of the advantages granted by the United States and European Union to most Central American and Caribbean countries, e.g. guaranteed sugar prices and export quotas, sugar industry suffered a lot; yields fell down, state companies closed down, thousands of jobs were lost, and these countries have been unable to subsidize their sugar industry, while the United States and to some extent Brazil, did so. The most striking examples of this collapse were Trinidad and Tobago, St Kitts and Nevis and Cuba. Nowadays, the Organization of American States is helping St Kitts and Nevis, El Salvador, Haiti and the Dominican Republic to rebuild their sugar industry, including rhum, agrofuel and electricity production (using bagasse in the latter case). In Jamaica, in 2008, the prime minister proposed to add 10% bioethanol to petrol, and the state is selling land to companies in order to plant sugar-cane and produce bioethanol.

In **Guatemala**, that has the highest production of sugar in Central America, five plants are producing 35 million gallons of ethanol, of which 80% is exported to Europe (for vodka and other alcoholic beverages) and to the United States. These five plants would be converted into agrofuel units in three or four months, according to Aida Lorenzo, director-general of Guatemala Renewable Fuels Association. Pantaleon Sugar Holdings of Guatemala, a giant producer of sugar, is building an agrofuel plant with an annual output of 14 million gallons of bioethanol. Guatemala uses a 10% blend of ethanol and gasoline.

In **El Salvador**, Cargill (Minneapolis), Crystalsev and Compañía Azucarera Salvadoreña are managing a dehydration plant that produces 60 million gallons per year while Gasohol de El Salvador of the Grupo Liza manages another plant that produces 50 million gallons. In 2006, this country exported 45 million gallons of ethanol to the United States. El Salvador is one of the four countries that recruited assistance through the bilateral agreement on biofuels between Brazil and the United States.

In **Nicaragua**, an important sugar producer Nicaragua Sugar Estates Ltd, is managing a plant that exports 50 million gallons of ethanol, mainly to Europe.

In **Costa Rica**, by the end of 2007, the Spanish company Biodiesel de Andalucía was running a plant producing biodiesel, while a local company, Liga Agrícola Industrial de la Caña de Azúcar, was managing a plant producing 50 million gallons of dehydrated ethanol. In 2006, the country exported 36 million gallons of bioethanol to the United States.

In the **Dominican Republic**, which is part of the bilateral agreement between the United States and Brazil, the government is rebuilding the sugar industry and investing in sweet sorghum, jatropha and sugar-cane for the production of biofuels. Tampa Energy of the United States was planning a US$50 million investment in a dehydration plant producing 50 million gallons of ethanol per year.

Jamaica exported 67 million gallons of ethanol to the United States in 2006. Three dehydration plants are being operated for the US market. Petrojam ethanol, a subsidiary of Petroleum Corp. of Jamaica (a state-owned company), produces 40 million gallons of bioethanol a year, while another plant produces 60 million gallons a year and belongs to ED&F Man, a London-based commodity and energy company. Also, JB Ethanol, a subsidiary of the agrocompany Jamaica Broilers, and Global Energy Venture, a West Africa-based corporation, specialized in oil and gas exploration, own plants that produce 60 million gallons, respectively. The Brazilian trading group Coimex has a joint venture in Jamaica with Petrojam to invest US$7.3 million in the rehabilitation of a 40-million-gallon ethanol production plant that will import all of its raw material from Brazil and ship all of its output to the US ethanol market.

In **Colombia**, Manuelita, the second-biggest sugar producing group and one of the main sugar producers in Peru is partly owned by Colombia's most powerful sugar industrialist and agrofuel supporter, Ardila Lülle.

Manuelita, like Pantaleon Sugar Holdings of Guatemala, is investing in sugar and bioethanol joint ventures through their Spain-based joint holding company, Grupo Colgua (Seedling, July 2007, pp. 20-24).

In 2008, the Colombian government's objective was to add 10% ethanol to gasoline and 5% biodiesel in diesel. Five plants were operating with an annual total output of 115 million gallons of bioethanol a year, and three plants were planned to produce 72 million gallons of biodiesel from palm oil.

Guyana, which is part of the Caribbean Basin Initiative (CBI), provides a key sea-port outlet for sugar and ethanol coming from the north of Brazil. But unlike the Caribbean island countries, which mostly dehydrate ethanol imported from Brazil, Guyana has the potential to develop its own low-cost sugar and ethanol production, with the prospect of much larger exports to the United States than are possible in other CBI countries.

Brazil's second biggest producer of biodiesel, Bio-Capital, intended to invest US$300 million in the purchase of some 50,000 hectares of land for cane cultivation and in the construction of an ethanol distillery. Bio-Capital was carrying out a similar venture in the state of Roraima in northern Brazil, that was expected to transport dehydrated ethanol to its Guyana facilities for duty-free exports to the United States.

Also the Spanish–Israeli group, Tanacama Ltd, carried out discussions with the Guyana Office for Investment and the Guyana Sugar Corporation in November 2006, with a view to setting up a pilot ethanol plant in the Canje river basin and to cultivate around 10,000 hectares with sugar-cane using Israeli crop technology. The initial capacity of the factory was expected to reach 80 million liters annually, and the investors hoped to increase that volume ten-fold within a decade (*Seedling*, July 2007, pp. 20-24).

Mexico consumed 89 million liters of gasoline Magna and 17.8 million liters of gasoline Premium, i.e. 107 million liters per day (2007); imports amounted to 42 million liters.

The annual production of the Cantarell oil field in the south-eastern part of the Gulf of Mexico has started to decline in 2007, the daily output being 140,000 barrels. It has been estimated that production at the Cantarell field would last until 2025. Finding new oil fields and drilling in more difficult conditions would require large investments from the federal government.

On the other hand, the use of gasoline containing 15% bioethanol (E15) would require the supply of 16 million liters of ethanol per day. Mexico would therefore need at least 40 refineries with an annual capacity of 150 million liters each; and 15.3 million tons of maize per annum (national production is around 20 million tons) and 83.7 million tons of sugar-cane per annum (national production is about 45 million tons).

The new ethanol plant, Biocyclos at Navolato in the State of Sinaloa has generated a polemic among Mexicans. For its promoters, this plant brings a rational solution to the problem of regional grain surpluses, while its opponents considered it as an immoral or even illegal enterprise, because the new law on agrofuels, issued at the beginning of 2008, prohibited the use of maize to produce ethanol, except in the case there was a surplus at the national level. But Mexico had imported about 8 million tons of maize in 2007 (Stolz, 2008).

Financed by Mexican private capital, mainly belonging to the de la Vega family, which owns the sugar group Zucarmex, Biocyclos is a very modern plant that contrasts with the old and polluting refineries of Zucarmex, of which the subsidiary Destilmex has obtained public subsidies amounting to €3.2 million in order to build Biocyclos. The director of the plant announced that the annual production will reach 350,000 liters of ethanol produced from 270,000 tons of maize. Exports to California and Arizona began in July 2008. In addition to ethanol, the plant will produce about 100,000 tons of maize paste with a high protein content, that could be used in human food. Destilmex has links with Minsa, one of the main producers of tortilla – the maize flat crepe which is the staple food of Mexicans. A large spoon of Maix – a brown flour derived from the process of ethanol distillation – mixed with nine spoons of ordinary maize flour, can produce tortillas containing 14% proteins compared with 9% for industrially made tortillas (Stolz, 2008).

Sinaloa's minister of agriculture, Jorge Kondo, justified the construction of the plant, stating: "Sinaloa is going to produce this year (2008) 5 million tons of white maize, 3 million tons of which will be for human consumption. It is costly to transport the surplus 2 million tons to other regions of Mexico. It is therefore better to transform them locally and to provide proteins to 20 million Mexicans who need them". But such position did not convince the opponents, and on 2 July 2008 the Mexican Federal Congress' permanent commission demanded details on the subsidies granted by the government to Destilmex, as well as to two other ethanol-plant projects (where maize is the raw material) [Stolz, 2008].

After having visited the on-going construction of Biocyclos in 2007, Mexico's president Felipe Calderon was impressed by the arguments developed by Mario Molina, Nobel Laureate in chemistry, against agrofuels, and became less supportive of this kind of fuels. In addition, during a regional summit meeting in Tuxtla, State of Chiapas, the agrofuel issue was the subject of a heated debate among the heads of state present at that summit. Daniel Ortega, president of Nicaragua, expressed his opposition to their use, which he qualified as a "lethal sin", while Mexico, Colombia and El Salvador supported their use. But the president of Mexico underlined that non-food crops or plants should be the raw materials, which excluded Mexico's white maize (Stolz, 2008).

The issue is even more sensitive in so far as many US automobile drivers in California, Arizona or Texas cross the border to fill their tanks in Mexico, where gasoline costs 30% less than in the United States. This transborder movement has markedly increased with the steep rise of oil price. The overall bill is doubly painful for the Mexican government which has to import, mainly from its northern neighbour, 40% of the refined fuel consumed in the country (Stolz, 2008).

Sorghum could be the appropriate crop species in Mexico for the production of bioethanol. This is a C-4 plant species, like sugar-cane, with a higher photosynthetic efficiency; it is the second crop in terms of production, just behind maize, and it is cheaper than maize; its water needs are lower, and it is more drought-resistant than maize and sugar-cane; finally it could be imported from the United States without any tariff. National production reached about 5.6 million tons in 2006, compared with about 10 million tons in the United States and about a similar figure in Nigeria. In Mexico, the States of Tamaulipas and Guanajuato are the leading producers.

An innovative process has been developed in Mexico in order to maximize the use of grain sorghum as a raw material for bioethanol production. It involves the mechanical decortication of the grains and a biocatalytic step aimed at making starch more susceptible to hydrolysis and conversion into ethanol. Enzymatic treatment before liquefaction or treatment with thermoresistant amylase improves the efficiency of amylolytic enzymes and yeast during the fermentation process. The overall result is to significantly reduce the duration of the whole process, thus saving energy and labour.

In the case of sweet sorghum, there are interesting advantages, when this crop species is compared with sugar-cane:

- the vegetation cycle is only three months, compared with nine to ten months in the case of sugar-cane; sweet sorghum can be harvested three times;
- the annual yield of sugar or bioethanol is comparable;
- sweet sorghum is drought-resistant and can be grown successfully in areas that suffer from weather extremes;
- sweet sorghum bagasse has a better nutrient content than sugar-cane bagasse.

Experiments carried out in the State of Nuevo Leon by Monterrey's Institute of Technology (Tecnológico de Monterrey) have shown that the varieties of sweet sorghum yielded 4 tons of fermentable sugars per hectare, 100-110 days after sewing (first harvest). If the varieties keep the same growth and behaviour during the following harvests, they could yield 20% more sugar and ethanol than sugar-cane.

Mexican researchers have concluded that both grain and sweet sorghum (which do not compete with food crops) could provide ethanol throughout the year with yields equal to those of maize and sugar-cane (or even higher).

In **Peru**, sugar output peaked at 1 million tons in 1975, then fell to 400,000 tons by the early 1990s. Since then, the sugar industry has passed into private hands again, and over the past decade (1990s-2001) production has returned to its historic peak – and in 2006-2007 was set to boom (*The Economist*, 2007a).

The change has been gradual; the government has sold its stake in the industry in tranches. But now, as in other parts of South and Central America, investors are attracted by higher prices for sugar because of its use for ethanol. Industry sources predicted that land under sugar-cane would expand by 10,000 hectares a year, more than doubling output over the next decade. That would turn Peru into an exporter – albeit not on the scale of Brazil or Colombia (*The Economist*, 2007a).

In 2006, local investors secured a controlling stake in Casa Grande, the largest sugar plantation. Bioterra, a Spanish company, planned a US$90 million ethanol-producing plant nearby. Maple, a Texas company, has bought 10,600 hectares of land in the northern department of Piura. Its plans call for an investment of US$120 million and ethanol production of 120 million liters a year. Brazilian and Ecuadorian investors are also active (*The Economist*, 2007a). Part of that attraction is that Peru has signed a free-trade agreement with the United States. Provided it can satisfy the concerns of the Democrats-controlled Congress in Washington, D.C., about the enforcement of labour rights, this agreement should be enforced by late 2008. It would make permanent existing trade preferences under which ethanol exported from Peru can enter the United States without duty (*The Economist*, 2007a).

Peru has also to take account of the fact that Colombia, Central America and the Dominican Republic all enjoy similar trade preferences as Peru would obtain. Colombia already produces 460 million liters a year of bioethanol, much of it for export. The second question is whether sugar-cane – a crop that needs a lot of water – is the best use of Peru's desertic coastal strip, with its precarious water supply. One of the country's achievements in the 1990s has been the private sector's development of new export crops. The latter might be therefore threatened by sugar-cane extension, mainly for bioethanol production and export (*The Economist*, 2007a).

Linkages between European financial institutions and Latin American businesses and agrofuel companies

In May 2008, Van Gelder and Kroes have published a report aimed at providing an overview of the involvement of private European financial institutions in the funding of companies producing and trading palm oil, soybean and sugar in Latin America, as well as companies processing these feedstocks into agrofuels in Latin America. They found 13 companies had linkages with 44 European financial institutions from ten European countries (Austria, Belgium, France, Germany, Italy, Netherlands, Portugal, Spain, Switzerland and the United Kingdom). Most companies only had links with a limited number of European financial institutions, but Bunge had links with 31 European financial institutions, Agrenco with 19 and Tereos with 13. Deutsche Bank (Germany) was the European financial institution that was most involved in financing Latin American agrofuel companies: a total of seven, of which three were of high importance and three of medium importance.

Agrenco Group is headquartered in Brazil and operates in Latin America, Europe, Africa, Middle East and Asia. Some 95% of the 1.6 million tons of soybeans marketed by the Group in 2005 originated in Brazil. In 2006, the Group announced investments of US$42 million (€32 million) in a port terminal in the Argentine province of Entre Rios that will allow the company to double soybean and grain shipments to 3 million tons. Also in 2006, the Group announced investments of US$150 million (€100 million) in three biodiesel plants in Brazil; the multi-seeds plants were expected to produce 380,000 tons (450 million liters) of biodiesel (Van Gelder and Kroes, 2008).

In 2006, Agrenco Group's total sales reached €976.5 million. At the end of June 2007, Agrenco Group owned total assets worth €634.7 million, financed by shareholders (5%), joint-venture partners (4%), banks (54%), trading partners (18%) and others (20%). But in October 2007, about US$350.2 million of new shareholder capital was raised, most of which was used to repay bank debts. Agrenco is listed on the São Paulo stock exchange; the dominant shareholder is Agrenco Holding, a Dutch investment company, that owned 48.31% of the shares (Van Gelder and Kroes, 2008).

Archer Daniels Midland (ADM) is one of the world's largest agricultural processors of soybeans, maize, wheat and cocoa. The company transforms these commodities into soybean meal and oil, corn sweeteners, flour, cocoa and chocolate, ethanol and biodiesel, as well as a wide range of other value-added food ingredients, animal feedstuffs and industrial products.

Headquartered in Decatur (Illinois), this publicly-owned US company had over 27,000 employees and more than 240 processing plants worldwide in 2007. Net sales for the fiscal year 2006-2007 amounted to US$44 billion, resulting in a net profit of US$2,162 million (Van Gelder and Kroes, 2008).

As one of the largest soybean exporters from Argentina, Brazil, Paraguay, Uruguay and Bolivia, ADM's global soybean crushing capacity amounted to 65,000 tons per day in 2007. In Latin America, ADM operates crushing plants with a total daily capacity of 12,650 tons in Brazil and 1,000 tons in Bolivia. ADM had a global biodiesel production capacity of 1.6 million tons (1,818 million liters) per year, of which 205 million liters were produced in Brazil in 2007.

At the end of the fiscal year 2006-2007, ADM owned assets with a total value of US$25,118 million that were financed by shareholders (45%), banks (3%), bondholders (18%), trading partners (29%), tax authorities (2%), and others (3%). ADM is listed on the New York stock exchange and at the end of September 2007, the European financial institutions, Axa, Barclays and Deutsche Bank, owned significant shareholdings in ADM (Van Gelder and Kroes, 2008).

Brasil Ecodiesel is Brazil's largest producer of biodiesel. Annual production amounted to 496 million liters in 2007, which equalled 56% of the country's total output of biodiesel. While the company maintained six operational plants with a combined annual biodiesel production capacity of 640 million liters, it was expanding its annual production capacity to about 1,310 million liters (2008).

At the end of 2007, Brasil Ecodiesel owned total assets worth €213 million that were financed mainly by shareholders (61%), and banks (25%). The company is listed on the São Paulo stock exchange. Eco Green Solutions, a fund of the Deutsche Bank, owned 35.80% of the shares of the company (Van Gelder and Kroes, 2008).

Bunge is a US agribusiness and food company founded in 1818 in the Netherlands and headquartered in White Plains (New York). It had over 22,000 employees in over 30 countries. The company supplies fertilizers to farmers in South America, produces, transports and processes oilseeds, grains and other agricultural commodities worldwide. It produces food products for commercial customers and consumers, and supplies raw materials and services to the agrofuels industry.

Bunge's soybean crushing capacity amounted to 30,100 tons per day in Brazil and 27,400 tons per day in Argentina in 2007. Bunge also owns crushing plants in Denmark, France, Germany, Italy and Spain, making it the largest soybean crusher in the European Union.

In Argentina, Bunge owns a 50% shareholding in Ecofuel, a joint venture with AGD, producing 253 million liters of ethanol per year. Bunge also planned to build another ethanol plant with a capacity of 127 million liters per year. In September 2007, Bunge acquired Agroindustrial Santa Juliana, a sugar-cane mill and ethanol plant located in the State of Minas Gerais, Brazil, with a view to expanding the processing capacity from the present 1.6 million tons of sugar-cane to 4.0 million tons per year (Van Gelder and Kroes, 2008).

In 2006, Bunge's net sales amounted to US$2.6 billion, resulting in a net profit of US$521million. The company's assets were valued at US$14,347 million (€9,483 million); they were financed mainly by shareholders (40%). Banks played a more modest role, financing 7% of total assets directly. But indirectly their role is larger as their revolving credit facilities are used as back-up for bond issuances. Bunge is listed on the New York stock exchange, and Axa and Barclays owned 4.10% and 2.32% of Bunge's shares, respectively, at the end of 2007 (Van Gelder and Kroes, 2008).

Cereol was one of the largest edible oil trading, crushing and refining companies in Europe. In October 2002, the company was acquired by Bunge and later renamed into Bunge Finance Europe. To finance its working capital needs, Bunge Finance Europe uses a large revolving credit facility from an international banking syndicate which is renewed regularly. In December 2006, Bunge Finance Europe entered into a three-year revolving credit agreement with a banking syndicate arranged by BNP Paribas (France) and HSBC Bank (United Kingdom). The facility expires in January 2010 with an aggregate borrowing capacity of US$600 million (Van Gelder and Kroes, 2008).

Cargill, a privately-owned US company, is the largest commodity trader in the world. It is an international provider of agricultural services, food ingredients and applications, fertilizers, salt and steel products and services, grains, oilseeds and other agricultural commodities. Cargill is headquartered in Minneapolis (Minnesota) and had 158,000 employees in 66 countries in 2007. Its annual sales reached US$88.3 billion, in the fiscal year 2006-2007, with a net profit of US$2,343 million (Van Gelder and Kroes, 2008).

Cargill is one of the most important soybean traders and crushers in Latin America: 15,700 tons per day (crushing capacity) in Brazil; 25,700 tons per day in Argentina; and 3,000 tons per day in Paraguay.

In 2006, Cargill acquired a 63% shareholding in Cevasa (Central Energética Vale do Sapucaí Ltda.), in Patrocinio Paulista (State of São Paulo). Cevasa's annual processing capacity of 1.4 million tons of sugar-cane generated 125 million liters of ethanol. Cargill also acquired a 43.75 percent share in Itapagipe mill (Usina Itapagipe Açúcar e Álcool Ltda.), in the State of Minas Gerais, and had a share in TEAS, the ethanol export terminal in Santos, State of São Paulo (Van Gelder and Kroes, 2008).

At the end of May 2007, Cargill owned assets with a total value of US$55.8 billion (€37.1 billion). The dominant shareholders of Cargill Inc. are around 80 members of the Cargill and MacMillan families, which together own about 85% of the company. It is not likely that European financial institutions are important shareholders of Cargill Inc. (Van Gelder and Kroes, 2008).

Clean Energy Brazil is a British investment fund, investing in Brazil. It is being managed by Temple Capital Partners, a partnership between Czarnikow Sugar (United Kingdom, the world's leading market services provider for sugar and ethanol), Agrop (Brazil, a leading agricultural and industrial processing consultancy and service provider) and the investment bank Numis Securities, which is part of Numis Corporation (United Kingdom). The company's aim is to participate in the development of sugar-cane businesses with an ideal critical mass in excess of 30 million tons of annual cane-crushing capacity.

Clean Energy had investments in:
- Santa Cruz de Montecastelo crushing plant in Parana State, which will have a crushing capacity of 2.3 million tons of sugar-cane (49%);
- Santa Monica crushing plant in Parana State, with a similar crushing capacity as Santa Cruz de Montecastelo (49%);
- Usaciga crushing mills in Cidade Gaucha (Parana State), the crushing capacity of which was to be expanded from 2.3 million tons to 9 million tons per year in five years time (49%);
- Rio Parana crushing plant in Eldorado (Mato Grosso do Sul State), with a crushing capacity of 2.3 million tons of sugar-cane (49%).

Investments were being planned in:
- Agua Limpa distillery in Santa Fé de Goiás (Goiás State), with a crushing capacity of 1.6 million tons of sugar-cane and a production of 137 million liters of ethanol (100%);
- Pantanal distillery in Sidrolandia (Mata Grosso do Sul State), with a crushing capacity of 1.5 million tons of sugar-cane and a production of 135 million liters of ethanol (92%).

As the company was set up in September 2006, its total income amounted to US$3.8 million by the end of April 2007, with a net profit of US$2.1 million. It owned total assets worth US$192.6 million, mainly financed by shareholders (US$185.4 million) [Van Gelder and Kroes, 2008].

Cosan is one of the world's largest producers of sugar and ethanol. In 2007, it employed 39,000 persons and owned 17 manufacturing units in Santos, in the State of São Paulo, and the largest port in South America. Cosan's key figures for the 2006-2007 harvest were :
- net sales, €1.4 billion;
- sugar-cane grinding, 36.1 million tons;
- sugar production, 3.2 million tons;
- ethanol production, 1,322 million liters;
- direct employment, 39,000 persons;
- cultivated area : 580,000 hectares.

On 30 April 2007, Cosan's total assets were worth €2,434 million, mainly financed by shareholders (26%) and bondholders (35%). Cosan is listed on the São Paulo and New York stock exchanges. Cosan Limited, a Bermuda-based company, owned by Ruben Ornetto, chairman of the board of directors of Cosan, owned 51% of the shares of Cosan. No European financial institutions seemed to own a significant amount of shares of Cosan (Van Gelder and Kroes, 2008).

Infinity Bio-Energy Ltd. is a company that produces ethanol from cane sugar. It was founded in March 2006 and since then made a number of acquisitions of Brazilian ethanol sugar mills; it owned four production facilities consisting of about 13 mills located in the States of Minas Gerais and Espirito Santo. The combined crushing capacity of these mills was estimated at around 5.9 million tons per year. Furthermore, Infinity Bio-Energy bought a 51% share in Montasa, a sugar-cane processing mill located in Montanha, State of Espirito Santo, whose crushing capacity in 2006 amounted to 1.5 million tons, fully dedicated to the production of ethanol. In 2007-2008, the company expected to produce 207 million liters of ethanol (Van Gelder and Kroes, 2008).

From April to September 2007, the company recorded net revenue of US$57 million, and ethanol sales represented 72% of total revenue. On 31 March 2007, Infinity Bio-Energy owned assets worth US$383 million (€255 million), mainly financed by shareholders (61%) [Van Gelder and Kroes, 2008].

Louis Dreyfus, a French privately-owned company, is one of the largest commodity traders in the world. Its main activities consist of worldwide processing, trading and merchandizing of various agricultural and energy commodities. The Louis Dreyfus Group is also significantly involved in the ownership and management of ocean vessels; in the development and operation of telecommunication infrastructures; and in real estate development, management and ownership. Louis Dreyfus companies are present in over 53 countries, with major offices in Beijing, Buenos Aires, London, Paris, São Paulo, Wilton (Connecticut) and Memphis (Tennessee). Aggregate average annual gross sales in recent years have exceeded US$20 billion (Van Gelder and Kroes, 2008).

Through SACEIF Louis Dreyfus & Cia., its Argentine subsidiary, the Group owned and operated the General Lagos crushing plant and port facility on the Parana River with deep-water access to large export-bound, ocean-going vessels. With a crushing capacity of 12,000 tons a day, it is one of the largest and most efficient oilseed plants in the world. Another subsidiary, Coinbra, owns and operates oilseed crushing facilities in Brazil with a combined crushing capacity of over 8,000 tons a day and a combined oil-refining capacity of over 600 tons a day. Louis Dreyfus is also trading soybeans in Paraguay and Uruguay.

The shareholders, headed by the French Louis Dreyfus family, are the most important financial stakeholders. But the company also uses bank loans to finance its operations (Van Gelder and Kroes, 2008).

Pure Biofuels Corp. is a Peruvian energy company founded in 2006. Although it is planning to become a leader in Latin America's agrofuels industry, until the end of 2007, the company did not generate any revenues from production. The company's biodiesel production plant, the Callao Port facility near Lima, started production in 2008 with an annual capacity of 198 million liters, with room for expansion. In December 2007, Pure Biofuels announced the completion of the company's acquisition of InterPacific Oil S.A.C.'s biodiesel production operation, Peru's largest and longest running biodiesel processor. This facility was expected to increase its capacity up to 38 million liters a year. The annual capacity for the combined operation was expected to exceed 235 million liters by mid-2008, making Pure Biofuels one of the biggest biodiesel producers in South America (Van Gelder and Kroes, 2008).

Santelisa Vale has been created from a merger of Vale do Rosario and Santa Elisa in October 2007. These two companies previously belonged to the Crystalsev Group. Santelisa is the main shareholder of Crystalsev. In 2007-2008, 240,000 hectares have been cultivated with sugar-cane, and sugar production amounted to 1.1 million tons and that of ethanol reached 723 million liters. The company expected to double its sugar-cane grinding capacity to 35 million tons for the harvest of 2010-2011. Santelisa Vale owned six factories, mainly in the State of São Paulo.

In 2006, Santa Elisa and Global Foods Holding (United States) set up the joint venture Companhia Nacional de Açucar e Álcool (CNAA). By 2008, the joint venture intended to build and operate four sugar and ethanol production facilities, with the capacity to crush 20 million tons of sugar-cane per year. CNAA would also develop 120,000 hectares of sugar-cane plantations in Minas Gerais and Goiás, which would make CNAA one of Brazil's top three sugar producers. Santa Elisa has a 28% share in CNAA.

Santelisa's main shareholder is the Brazilian Biagi family, with a 72% capital stake, followed by investment bank Goldman Sachs with a 17% share (Van Gelder and Kroes, 2008).

São Martinho is a company that purchases, cultivates, harvests and crushes sugar-cane. In 2007, it owned two sugar and ethanol mills in the State of São Paulo: the Iracema mill in Iracemápolis and the São Martinho mill in Pradópolis. In 2006-2007, the company crushed 9.3 million tons of sugar-cane and produced 678,000 tons of sugar and 394 million liters of ethanol. In addition, the company was building a third mill, Boa Vista, in the city of Quirinópolis in the State of Goiás, with production starting in 2008-2009 (1.7 million tons of crushing capacity and 95 million liters of ethanol).

Shareholders (58%) play the most important role in the financing of São Martinho; banks play a significant role (17%). São Martinho is listed in the São Paulo stock exchange (Van Gelder and Kroes, 2008).

Tereos is a French cooperative group: the beet growers are both the company's suppliers and shareholders; they control the processing facilities for their own raw materials. The group brings together 14,000 farmers, grouped into 13 cooperatives. Tereos held a total of 35 industrial facilities and employed 17,000 permanent persons in 2007. It is based in Europe (France and the Czech Republic), South America (Brazil) and Africa (Mozambique and La Réunion). The company´s head office is Lille.

In 2007, Tereos' sales amounted to €3.1 billion; the cooperative cultivated 930,000 hectares; sugar and glucose production reached 4.3 million tons and alcohol production 1,300 million liters.

In 2000, Tereos Group was established in the State of São Paulo through the Brazilian subsidiary Açucar Guarani (63% of the equity is held by Tereos). Açucar Guarani owns three factories: Severinia, Cruz Alta and Sao José; in 2006-2007, sugar production was 1.2 million tons (from 8.2 million tons of sugar-cane) and ethanol production 309 million liters. Its grinding capacity was expected to increase to 12.7 million tons in 2008 and to 14.2 million tons in 2009. At the end of September 2007, Tereos owned total assets worth €3,989 million (27% by shareholders and 21% by the banks) [Van Gelder and Kroes, 2008].

AGROFUEL PRODUCTION IN SUB-SAHARAN AFRICA

Investments

Africa is attracting investments in agrofuel production. For instance, by early 2007, the Tanzanian government disclosed that it was negotiating with 11 foreign companies for investment in agrofuel crop production in the country. Petrobrás, Brazil's oil company, has struck deals for bioethanol imports and technology transfer with several African countries, from Senegal to Nigeria. India has pledged US$250 million to a West African Biofuels Fund, and China has ensured a long-term cassava supply from Nigeria for its domestic ethanol plants. The United Kingdom and Brazil have signed a trilateral agreement with Mozambique (*Seedling*, July 2007, pp. 36-45).

Examples of corporate investments in agrofuel production in sub-Saharan Africa are the following:
- Viscount Energy (China) has signed a memorandum of understanding with the Ebonyi State government to set up a US$80-million bioethanol factory in Nigeria using both cassava and sugar cane;
- 21st Century Energy (USA) planned to invest up to US$130 million over the five period 2007-2011 in the production of bioethanol from sugar-cane, maize, sweet sorghum, and later on to manufacture biodiesel from cottonseed and cashew nut residues in Côte d'Ivoire;
- Bioenergy International (Switzerland) planned to set up a 93,000-hectare jatropha plantation with a biodiesel refinery and an electrification plant in Kenya;
- Sun Biofuels (United Kingdom) in association with the Tanzania Investment Centre (TIC), has acquired 18,000 hectares for jatropha production;
- Alco Group (Belgium) bought South Africa's NCP Alcohols, Africa's largest producer of ethanol in 2001;
- MagIndustries (Canada) acquired a 68,000-hectare eucalyptus forestry plantation and was constructing a 500,000-tons-per-year wood-chipping

plant near the port city of Pointe-Noire in the Republic of Congo; the wood chips will be shipped to Europe for use as biomass;
- Aurantia (Spain) was investing in oil-palm plantations and possibly four biodiesel refineries in the Republic of Congo;
- Dagris (France) was also investing in the development of biodiesel production from cottonseed oil in Burkina Faso through its local oil processor, SN Citec;
- Socapalm and Socfinal (Belgium) planned to extend its 30,000-hectare oil-palm plantation in Cameroon (Seedling, July 2007, pp. 36-45).

Jatropha curcas, a source of biodiesel

Jatropha curcas belongs to the Euphorbiaceae family. Called physic nut or purging nut, it is a shrub and even a small tree with bright red flowers, indigenous to Central America, which Portuguese traders took to Africa and Asia as a hedge plant. Its oily seeds can be used to produce biodiesel from their non-edible oil. It can be cultivated on marginal soils and can therefore become an interesting source of income for small and poor farmers in developing countries. It has been claimed that one jatropha plant could supply one liter of biodiesel per year for 40 years, and thus it would provide a decentralized source of energy in remote areas that are not connected to the electricity grid. Women would be involved to a very large extent in this task, which would help their revenue-earning potential (*Seedling*, July 2007, pp. 34-35).

For centuries, African farmers have been using *Jatropha curcas* bushes as live fences meant to keep back the encroaching Sahara and Kalahari deserts. During a drought, the shrubs simply drop their leaves and keep pumping out seed pods. Livestock will not eat the shrub and pests do not appear to parasite it. Living on poor soils, with very little water, *J. curcas* will likely last 50 years (Palmer, 2007).

In Mali, the Royal Tropical Institute in Amsterdam, that has been working to develop jatropha as a commercial fuel, estimated there are 22,000 linear kilometers (fences) of the shrub. A number of small-scale projects aimed at solving local problems – the lack of electricity and rural poverty – are blossoming across Mali to use the existing supply of jatropha oil to fuel specially modified generators in villages far off the electrical grid (Polgreen, 2007).

In the region of Koulikoro, the company Mali Biocarburant is producing biodiesel from jatropha seeds collected from hedges of the shrub along the agricultural plots, and not from plantations that would take land normally devoted to millet. The Union of cooperatives of jatropha producers of Koulikoro owns 20% of equity of Mali Biocarburant, the rest of equity belonging to Dutch shareholders (*Spore*, CTA, August 2008, n° 136, p. 4).

If *Jatropha* proves a success as the source of cheap and decentralized source of agrofuel, it should not hamper the country's food production, nor lead to a concentration of land ownership that could drive the poorest farmers off their fields and into deeper poverty (Polgreen, 2007).

It was shown in several parts of the world, that *Jatropha curcas* oil burns with one fifth the carbon emission of fossil fuels, making Africa's infertile land a potentially fertile source of energy. Scientists estimated that if even a quarter of the continent's arable land were plowed into jatropha plantations, output would surpass 20 million barrels a day. That would be good news for Europe, where the demand for biodiesel is growing. With maize prices soaring, scientists are experimenting with alternative non-food crops in the laboratory; *Jatropha* species and a very few similar plants (e.g. *Pongamia*) are drawing their interest (Palmer, 2007).

Experimental *Jatropha* plantations are now popping up from Kenya to Ghana, to South Africa. There are also fields in Benin, Senegal and Nigeria, and thousands of hectares in Burkina Faso (Palmer, 2007).

Norwegian, Indian and British groups are buying up or leasing enormous swaths of African land to plant *Jatropha curcas*. The United Kingdom-based D1 Oils has bought 20,000 hectares in Malawi. In Zambia, D1 Oils Zambia has signed a contract with about one thousand farmers in the southern part of the country (Choma and Kalomo) in order to plant jatropha on 174,000 hectares over four years (2008-2011). Another development project aimed at fostering rural development in northern Zambia is the Agricultural Triangle Block of the Kachumu Network of Community Development – a 15,000-hectare public-private partnership; about 100 persons had been already employed in 2008 to plant jatropha. D1 Oils Zambia provides seeds and technical assistance, and guarantees the purchase of the harvest. The Zambian government has appointed the company as a member of the board of the working group on renewable energy in order to develop a national biofuel policy (*Spore*, CTA, August 2008, n° 136, p. 4).

India's IKF Tech has requested government leases for a total of 150,000 hectares of land in Swaziland, Mozambique and South Africa. Worldwide Bio Refineries, a British firm, has 40,000 hectares set aside for production in Nigeria, with planting to begin in 2008. Ephraim

Boakye-Gylmah, a supervisor at the AngloGold Ashanti gold mine in Obuasi, began planting jatropha seedlings on reclaimed mine wastes in Central Ghana in 2006. So far, however, most ventures are still in the planting and growing stages; in 2007, the continent was producing almost no jatropha oil (Palmer, 2007).

Investors are skeptical that Africa has infrastructure to support full-scale oil production, which requires refinery and transportation. African farmers have also to be convinced of the interest of the new crop. In 2004, the Adventist Development and Relief Agency used a US$50,000 grant from the United Nations Development Programme -UNDP- to persuade 3,000 farmers into setting aside one-half hectare each for jatropha, to try to develop a supply of seeds for farmers. But no one has been willing to buy the seeds. Jack Holden, director of Goldstar Biodiesel, an agrofuel firm, on one hand stated that if there was today a good refinery in place, it could not operate because there was no feedstock yet; and on the other hand, that African farmers should move quickly towards planting the trees (Palmer, 2007).

Other agrofuel ventures

In **Ghana**, the local companies, Biodiesel One (producing biodiesel from a 12,000-hectare jatropha plantation) and Anuanom Industrial Bio Products, had financial difficulties and tried to convince the government to bail them out. In December 2006, the government pledged about US$2 million to support large-scale jatropha cultivation in the centre of the country, with over US$300,000 going directly to Anuanom. It was also reported that the state-owned oil-trading company, BOST, had offered to purchase all the biodiesel produced in Ghana, giving the local companies a much-needed guaranteed market (*Seedling*, July 2007, pp. 36-45).

Other corporations have been attracted to Ghana, e.g. D1 Oils (based in the United Kingdom) set up its own subsidiary, Israeli investors have been looking into the construction of a biodiesel factory in the central region, A1 Biofuels (based in Canada) and its local partner, Sahel Biofuels Development Company, based in Niger, were preparing sites for large-scale jatropha plantations across the Sahel region of West Africa and planning to build a biodiesel refinery in Ghana with a capacity of 25 million liters per year (*Seedling*, July 2007, pp. 36-45).

In **South Africa**, agrofuels became one of the priorities of the government's Accelerated Growth Initiative (ASGI-SA). The Industrial Development

Corporation and the Central Energy Fund announced plans to invest US$437 million in five agrofuel projects, and South African commercial maize farmers invested money in a new company, Ethanol Africa, which claimed to build eight ethanol plants in the main maize-producing area. The ethanol industry was told to use only yellow maize, to ensure that there was no competition with white maize, a staple food. Some analysts were sceptical about this venture's chances of success. In fact, in 2007, South Africa was running a deficit in its maize production, instead of the expected surplus. In addition, the extra demand from the ethanol producers, combined with a drought in Southern Africa, have caused maize prices to soar, with a rate four times the level predicted in the Biofuels Strategy. Ethanol Africa's first plant, to be built at Bothaville in the northern Free State, has not progressed, probably because the investors were waiting to see whether the government would subsidize the industry (but why subsidize it, when farmers are not). Furthermore, the initiative of the Eastern Cape government to make 3 million hectares of communal land available for agrofuel production, including the planting of 70,000 hectares of canola for export by German investors, has been questioned. Consequently, the statement that "Southern Africa has the potential to be the Middle East of biofuels" by Andrew Owens, chief executive officer of the United Kingdom's Greenery, at an agrofuel conference in Cape Town in January 2007, should be taken with care (*Seedling*, July 2007, pp. 36-45).

In **Ethiopia**, the government is trying hard to attract investment in the agrofuel industry. The most popular energy crop is jatropha, followed by castor beans and some oil-palm in the coffee-growing regions, all of which are to be used to produce biodiesel. There are also attempts to set up an ethanol industry and to introduce new, specially bred varieties of sorghum, maize and sunflower. The German company Flora Ecopower invested US$77 million in the Oromia Regional State and negotiated the purchase of over 13,000 hectares of land in the Fadis and Miks woredas (districts) of the East Hararghe zone for the production of biodiesel. It has signed an agreement with the regional farmers' association by which 700 farmers were each ceding two hectares of land for a period of five years. According to environmental organizations, the land granted fell, to a large extent, within the boundary of the Babile Elephant Sanctuary; they also underlined that no environmental impact assessment had been carried out. The Federal and the Oromia regional governments have been required to tackle the issue of damage to a protected ecosystem (*Seedling*, July 2007, pp. 36-45).

Another company, Sun Biofuels, has signed a lease agreement with the Benshangul Gumuz Regional State government for 80,000 hectares of land. It has also purchased 80% of the National Biodiesel Corporation of Ethiopia as part of its programme to strengthen its presence in Ethiopia prior to investing in the whole of East Africa (*Seedling*, July 2007, pp. 36-45).

With a number of foreign agrofuel companies operating in the country and 196,000 hectares officially granted for agrofuel production, Ethiopia has identified 17.2 million hectares as suitable for jatropha cultivation, of which 1.7 million, located in the Borema, Bale and Arsi zones, were regarded as highly suitable. The Ethiopian government stated that, while more than 4 million people suffered from food insecurity, the agrofuel industry should not deprive farmers from growing food crops particularly in the lowlands (*Seedling*, July 2007, pp. 36-45).

In **Mauritius**, which is the largest supplier of sugar to the European Union, holding 38% of the quota within the Sugar Protocol, the ethanol business is controlled by Alcodis, a joint venture company that is part of the Belgian shipping conglomerate Alco Group. The latter handles about 8% of the ethanol traded worldwide, most of it sourced from its Brazilian operations, but some is also coming from both its subsidiary in South Africa, NCP Alcohols, and its plant in Mauritius. In 2004, Alcodis shipped over 3.5 million liters of ethanol to the European Union from Mauritius – tax-free because of its status as an ACP (African, Caribbean and Pacific) country. Mauritius has been negotiating an assistance package with the European Union to restructure its sugar industry; €300 million would be provided to the formation of a sugar-cane “cluster” in the country that aims at consolidating the small-scale sugar production and reorienting it towards energy production, primarily ethanol (*Seedling*, July 2007, pp. 20-24).

Conclusions

According to Grain, a Barcelona-based non-governmental organization that promotes the sustainable management and use of agricultural biodiversity based on people’s control over genetic resources and local knowledge, agrofuels are not expected to improve the life of the majority of African people. This severe judgement is based on the fact that they cannot buy agrofuels and do rely on wood, charcoal and dung to meet their basic energy needs. Even in Nigeria, a leading oil exporter, biomass, mainly firewood, still meets the energy needs of up to 91% of the country’s households. Grain considers the agrofuel boom in Africa will mainly benefit foreign corporations owning industrial plantations. Nobody can deny that private interests are involved, but this does not necessarily imply that small farmers cannot participate in agrofuel production and draw some income from it, as it is the case in Brazil and some Central American and Caribbean countries. It is the duty of the governments to ensure a fair distribution of income and to strike the appropriate balance between the various land uses.

AGROFUEL PRODUCTION AND INDUSTRY IN ASIA

In South Asia, with a population of over 1.5 billion people, an area of 5.1 million hectares and a fast economic growth rate, the demand of energy had risen by 64% since 1991, thus reaching 584 million tons of fuel in 2003-2004. In this region, more than 90% of that energy demand is met by fossil fuels, and more than 70% of oil demand was met, to a large extent, by imports. Biofuels may be therefore interesting alternative sources of energy, especially biodiesel made from oils extracted from *Jatropha curcas, Pongamia pinnata*, soybeans, mustard, oilseed-rape, groundnut and oil-palm (*Elaeis guineensis*), as well as from animal fats. Biodiesel is mixed with petrodiesel in motor-car fuel, and this blending prevents the polymerization of triglycerides into large saturated carbon chains (Linoj Kumar et al., 2006; Raju, 2006).

India

In January 2003, the Ethanol Blending Programme mandated the blending of 5% ethanol in gasoline. With limitations to the expansion of sugar-cane production in India, the mandate encouraged Indian sugar companies to expand into Brazil, and India has become a big importer of Brazilian ethanol. Reliance Industries, India's largest private sector company, was planning to build a large ethanol refinery in Brazil. It had also a US$500-million jatropha refinery under construction in Andhra Pradesh. In 2006, both Bajaj Hindusthan, India's largest sugar and ethanol manufacturing company, and Indian major Bharat Petroleum announced their plans for multi-million dollar acquisitions and expansions into Brazil's sugar and ethanol sector (Ernsting, 2007).

Most of the auto fuel consumed in India is diesel. The National Mission on Biodiesel, created in 2003, has set the ambitious goal of a 20% biodiesel blend by 2013. The government is looking at jatropha oil as the main feedstock, and in January 2005 a detailed project report was prepared for a pilot stage concerning 400,000 hectares of plantation of *J. curcas*.

The government's goal was to bring into production by 2012, 13.5 million of the 39 million hectares deemed available for jatropha production in the country. Several States have initiated biodiesel production programmes and have adopted the relevant policies (Ernsting, 2007).

Government policy and cooperation with companies

The Indian government has been very supportive for the production of agrofuels as India's response to both its rising oil import bills and mitigation of climate change through the reduction of emissions of carbon dioxide and greenhouse-effect gases. To that end, the government is using all administrative machinery, at the federal, State and district or panchayat levels. This means that both large- and small-scale operations and initiatives are being supported. For instance, Daimler-Chrysler encourages the production of biodiesel for its cars and other "modern vehicles", while Indian Railways leases its land to Indian Oil Corporation for agrofuel plantations to fuel its trains. The leading cement company, ACC, set up jatropha and castor bean plantations for energy to run its power plants (*Seedling*, April 2008, pp. 15-23).

Several States in India have set up a variety of incentives to promote agrofuel production, particularly biodiesel in association with corporations. For instance, in Uttarakhand, the State's Biofuel Board is promoting plantations under its joint forest management programmes. In Punjab's Agricultural University, the Department of Forestry and Natural Resources is evaluating 35 different source varieties of jatropha while training farmers in jatropha cultivation. In Central India, the Chhattisgarh Biofuel Authority was set up by the State government in 2005 with a single-minded focus on jatropha and ambitious targets to convert all state-owned vehicles to jatropha oil-powered ones. This was followed by the creation of a Chhattisgarh Renewable Energy Development Authority which claimed that by August 2007 it had sponsored jatropha plantations to the tune of about US$1 million in the State. In neighbouring Madhya Pradesh, the government has its own Biofuel Mission, with a view to bringing one million hectares of land under jatropha cultivation in 20 years, thanks to the training of farmers and the dissemination of higher-yielding varieties (*Seedling*, April 2008, pp. 15-23).

Some provincial governments have set up plantations for biodiesel production in association with corporations. In Andhra Pradesh, the Rain Shadow Areas Development (RSAD) Department has asked Sagar Sugars & Allied Products Ltd to be responsible for the jatropha nurseries.

There is also a new kind of partnership between the State, private companies and the panchayat (body of elected representatives at the village level). Called Rural Business Hubs (RBHs), these are being tested in selected locations throughout the country. For instance, D1 Oils plc, which is now controlled by the British Petroleum, is setting up three jatropha biodiesel hubs in Haryana. IKF Ltd, an information technology company that has diversified in biofuels, has expanded into 14 States, including Meghalaya and the north-east, with help from the Indian Council of Agricultural Research (ICAR), and has now moved to Thailand. In Andhra Pradesh, the State government has agreed to cover total costs for small and marginal farmers to convert their land to biodiesel plantations, particularly of pongamia (*Pongamia pinnata*) and jatropha (*Jatropha curcas*). Under the Andhra Pradesh Rural Employment Guarantee Scheme (APREGS), public-private partnerships have been forged, paving the ground for the expansion of 14 private companies, which included Nandan Biomatrix Ltd (which has a joint venture with D1 Oils), Titagarh Bio-Tech Ltd and Jatropha Growers and Bio-Fuel Development Cooperative Ltd (*Seedling*, April 2008, pp. 15-23).

Government support for the companies

In general the companies wanted more support, particularly at the national level. In 2006, biodiesel suppliers and others formed the Biodiesel Association of India (BDAI), which has become the main group lobbying for legal and policy changes to create a more industry-friendly environment. BDAI's main demands are: more land on which to grow the raw material; easy conditions for importing big volumes of biofuels until the local plantations deliver the feedstocks; a guaranteed price for biodiesel, to be raised from US$0.66 (Rs 26.50) to at least US$0.83 (Rs 33.0) per liter; tax exemptions and the creation of a national Biofuels Board, headed by the prime minister, to deal with all the key policy issues (*Seedling*, April 2008, pp. 15-23).

The Core Group on Biofuels, from the Federation of Indian Chambers of Commerce and Industry (FICCI), has recommended to the agriculture ministry a 10-year tax holiday for large-scale corporate jatropha farming. FICCI also called on the government to use the National Rural Employment Guarantee (NREG) scheme (under which the government has to provide 100 days of guaranteed waged employment per financial year to every rural household) to make villagers plant crops like jatropha. The sugar industry lobby – Indian Sugar Mills Association – is seizing the ethanol boom opportunity for more deregulation (*Seedling*, April 2008, pp. 15-23).

Not surprisingly, social movements have been complaining about the level of government support for the corporations. A People's Coalition on Biofuels is demanding a "pro-people energy policy" from the government. The latter, through the Planning Commission of India, is guaranteeing full support for renewable energy and favours the granting of tax incentives to make biofuels economically feasible. But the BDAI has been unhappy at the delays, particularly the indecision over government subsidies (*Seedling*, April 2008, pp. 15-23).

The truth is private industry has bounded ahead, in the absence of a coherent government policy. There are several reasons for this: opening up of the Indian economy to large enterprises, including foreign corporations; cheap production costs; affordable human labour; lax environmental regulation; and generous incentives (fostered by the competition between the provincial governments to attract the investments). By contrast, in China foreign stakes in agrofuel companies have been limited by law to 49% since 2007. All this means that it makes sense for the big foreign players to have operations in India for their global production. Those moving in include BP (D1 Oils) and Daimler (tied up with ADM and Bayer). Some of the Indian corporations, such as Praj, which deals with ethanol processing machinery, have become transnational corporations themselves and have therefore many crossing links with foreign companies (*Seedling*, April 2008, pp. 15-23).

Praj had a 60% share in a joint venture with the Netherlands-based company BioEnergy Europa B.V. and a 54% stake in the Brazilian firm Jaragua Equipamentos Industriais Ltda for ethanol production; it provided the equipment for the United Kingdom's first ethanol plant, commissioned by British Sugar; it was awarded machinery contracts for cassava-to-ethanol plants in Thailand; it owned an engineering firm in the United States; and it was present in another 40 countries. The Indian-American venture capitalist Vinod Khosla, who is promoting biofuel production worldwide, has bought a 10% share in Praj. The Japanese Marubeni Corporation also had a share in the company. In addition, Praj's chairman heads the Confederation of Indian Industry's National Committee on Biofuels. The company is also reaping the benefits of the Government's Special Economic Zones (SEZ), setting up a new production unit by the port in Kandla SEZ in Gujarat (*Seedling*, April 2008, pp. 15-23).

In Andhra Pradesh's port city of Kakinada, three or four biodiesel plants were planned. One of them – Natural BioEnergy Limited, set up in collaboration with an Austrian energy company and a US investment firm, was the first integrated oleo-chemical biodiesel facility in India.

Established in 2003, it started its operations in 2007 to produce biodiesel and glycerol from palm oil, jatropha and pongamia feedstocks. Most of its production will be exported, mainly to North America and East Asia (*Seedling*, April 2008, pp. 15-23).

Agribusiness companies are also benefiting from the Indian government support for agrofuels. For instance, Adi Biotech is moving into the export of jatropha seeds. Nuziveedu Seeds Pvt. Ltd., a hybrid seed firm, was working with General Electric to set up this US company's first wind project in India, in the Davengere district of Karnataka, for which it had also received support from the ministry of renewable energy, through the Indian Renewable Energy Development Agency (IREDA). Labland Biotech Pvt. Ltd, a plant biotechnology company from Mysore in Karnataka, was producing tissue-culture-derived jatropha plants for distribution in India, Africa and Latin America through D1 Oils plc. The company has also been shortlisted to partner with a Portugal-based company to develop about 1 million hectares of land in Mozambique for jatropha cultivation. Gujarat State Fertilizers and Chemicals Ltd (GSFCL) has also selected Labland Biotech as one of its two service providers for its 1,100-hectare jatropha plantations being developed in the harsh, saline regions of Kutch in Gujarat (*Seedling*, April 2008, pp. 15-23).

Bioethanol production

India's sugar-cane production (second biggest in the world behind Brazil) is a chemical-heavy, water-intensive monoculture. Nowadays, the planners want to develop sugar-cane as a multi-product crop, that is, one that can be used to produce other chemicals than sugar, e.g. bioethanol. India is also seeking to develop technology to produce bioethanol from sweet sorghum and sugar-beet.

Many companies have become part of the Sweet Sorghum Ethanol Consortium (SSERC), set up by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). This centre of the Consultative Group on International Agricultural Research (CGIAR) harvest plus centres is behind the world's first sweet sorghum ethanol project. By 2003, it initiated a programme aimed at developing hybrid varieties with higher sugar content than conventional sorghum, and at designing the process technology. The Consortium was joined by Tata, followed by Praj. Tata Chemicals was expected to build a pilot agrofuel manufacturing unit in Nanded in Maharashtra, to be operational in 2008-2009. In January 2008, the ICRISAT-NAIP sweet sorghum ethanol value chain development project was initiated, with Rusni Distilleries Pvt Ltd as part of the team.

Rusni built up its first distillery in the town of Rosales in the Philippines in January 2007; the company held a patent for the production of ethanol from sweet sorghum stalk. A similar project was also initiated in Kampala, Uganda, by a private company, JN Agritech International Ltd. The partnership with the Ugandan company was forged by the Rusni Distillery with the support of the Agri-Business Incubator at ICRISAT. The latter was also involved in another public-private partnership which, along with the German government's GTZ, the World Bank's IFC and the US Rabobank group, supported Southern Online Biotechnologies Ltd. with biodiesel expansion projects in alliance with the German Lurgi Life Science company (*Seedling*, April 2008, pp. 15-23).

Praj industries was working with Syngenta's proprietary tropical sugar-beet for the processing of sugar extracted from this variety adapted to tropical conditions (*Seedling*, April 2008, p. 15-23).

Jatropha cultivation and biodiesel production

Jatropha (locally termed ratanjyot, jungle erandi, kadaharalu, or jepal, depending on the region) is being promoted as the most appropriate agrofuel crop.

The New Delhi-based Tata Energy Research Institute (TERI), specialized in biotechnology research, has launched a 10-year US$9.4 million programme to intensify the cultivation of *Jatropha* (2006). According to Alok Adholeya, who leads the programme involving 25 researchers, this shrub can annually produce, and for over 30 years, 2 to 3 kg of fruits from which it is easy to extract oil (35% of weight) that can be transformed into biodiesel. Eight kg of fruits could produce 3 liters of biofuel (Ihaddadène, 2007).

Over the period March 2007-March 2008, the researchers of TERI were to convince farmers to participate in a large-scale trial of plantations on 8,000 hectares in the State of Andhra Pradesh, south-eastern India. Some 20,000 to 30,000 farmers were to be involved and trained to manage this crop in the most efficient way (Ihaddadène, 2007).

Simultaneously, TERI's researchers are trying to improve the productivity of jatropha, through root mycorhization, so as to compensate the very low soil fertility. Such inoculation process would increase yields by 20% to 30%. In addition, genes controlling the production of oil are being sought so as to develop a genetically modified *Jatropha* in five years (Ihaddadène, 2007).

It should be underlined that irrigation, or at least improving cultivation conditions of jatropha, increases the average yields from 1.1-2.75 tons per hectare to 5.25-12.5 tons per hectare. Cultivation of the plant in marginal areas may therefore expand to more fertile and irrigated lands, which might be the case in India. Small farmers may also have to face the competition of big corporations interested in increasing the production of oil and biodiesel. In India, where the government has targeted 13.5 million hectares of "wasteland" for jatropha cultivation by 2012, it has been reported that companies were trying to buy land from farmers to set up jatropha plantations and industrial biodiesel plants (*Seedling*, July 2007, pp.34-35).

The Indian government's objective is to use large areas of degraded and low-fertility land, and transform them into plantations of oilseed species for the production of agrofuels. About 63 oilseed species belonging to 30 plant families are considered as potential sources of agrofuels. *Jatropha curcas* and *Pongamia pinnata* seem the most appropriate in the Indian context. These plantations could create jobs and thus reduce the flow from rural areas to the cities; the participation of women in the management of these plantations could improve their standard of living thanks to a new income.

In 2005-2006, the ministry of rural development provided financial support to nine States for the production of about180 million seedlings of jatropha. In 2006, the Indian Council of Agricultural Research identified for commercial cultivation in the semi-arid and arid regions a jatropha variety – SDAUJ I – which produces seeds with 49.2% oil content. At the Department of Biotechnology work is being carried out to discover which varieties of jatropha is best suited for biodiesel production, and to develop these varieties. The National Oil Seeds and Vegetable Oils Development Board (NOVOD) at the ministry of agriculture are also overseeing a countrywide project for the identification and development of elite jatropha planting material. The Uttarakhand Biofuel Board has established a jatropha gene bank to preserve high-yielding seed varieties (*Seedling*, April 2008, pp. 15-23).

The first areas to be targeted for jatropha cultivation are the so-called "waste lands". In 2005, the ministry of rural development produced a *Wasteland Atlas of India*, and a study from the Tata Energy Research Institute (TERI) identified six categories of waste land as suitable for jatropha plantation. The Indian Space Research Organisation also has an ongoing remote-sensing project to identify waste-land sites for plantations (*Seedling*, April 2008, pp. 15-23).

In Rajasthan, the State government has designed a policy which permits waste land to be leased out to private companies and government enterprises for up to 20 years. Although 70% of these “culturable wastelands”, as they are called, were to be allowed to farmers’ groups and only 30% to companies, there was concern among environmental organizations that companies might take over more than the permitted amount, or that huge areas be allowed to single corporations like DMC International. Village leaders are therefore demanding legal recognition of their customary grazing lands (there are about 7.5 million pastoralists in Rajasthan) [*Seedling*, April 2008, pp. 15-23].

In the State of Orissa, the Orissa Renewable Energy Development Agency (OREDA) which is the leading government agency in charge of biofuel was planning jatropha plantations in the districts of Kalahandi, Bolangir and Korapur, as a poverty alleviation programme. Long-time activists, who have been fighting the takeover of land by large companies, demanded that local people should be able to use the crops and oil extracted to meet their own energy needs (*Seedling*, April 2008, pp. 15-23).

If vast areas of land were to be turned to jatropha plantations, some water will be required for irrigation, however hardy the crop species is, in order to obtain good yields of seeds and oil. This has raised concerns about the distribution of water among farmers and consumers. The governments in Punjab, Karnataka, Maharashtra and Andhra Pradesh were offering to subsidize drip irrigation for jatropha plantations. Industry representatives in Tamil Nadu were requesting a similar scheme, and the State government was seeking help from the national government, because it could not afford to pay such a subsidy. Water being an increasingly scarce resource, jatropha cultivation and its irrigation needs will inevitably compete with other uses, agricultural and non-agricultural (*Seedling*, April 2008, pp. 15-23).

Forestry departments are involved in jatropha spreading. For instance, the Centre for Research and Application in Plant Tissue Culture in Hisar, Haryana, has supplied over 100,000 jatropha plants to the farmers, and the Haryana Forest Department was creating 300 hectares of model jatropha plantations. Similarly, the Forest Department in Himachal Pradesh was distributing jatropha saplings for planting (*Seedling*, April 2008, pp. 15-23).

In north-eastern India, D1 Oils signed an agreement with the Williamson Magor Group, one of the world’s largest producers of tea. In Mizoram, the State government had signed a memorandum of understanding with

D1 Oils in 2005 for the supply of jatropha seeds. Godraj Agrovet Ltd, a big agroindustrial company, was already producing palm oil, and in 2007 announced plans to establish 20,000 hectares of jatropha in the State (*Seedling*, April 2008, pp. 15-23).

The following companies are investing in jatropha plantations in Asia, and particularly in India:
- British Petroleum (BP) has planned to establish 100,000 hectares of jatropha plantations in Indonesia to feed a 350,000 ton-per-year biodiesel refinery;
- Van Der Horst Corporation (Singapore) was building a 200,000-ton-per-year biodiesel plant in Juron Island in Singapore that could be supplied by jatropha plantations belonging to the company in Cambodia and China, and possible new plantations in India, Laos and Burma (Myanmar); in Myanmar, an extensive jatropha planting campaign was taking place, with a first target of 200,000 hectares within three years, and eventually 3.25 million hectares later on;
- Mission Biofuels (Australia) hired Agro Diesel of India to manage a 100,000-hectare jatropha plantation and a contract farming network in India to supply its Malaysian and Chinese biodiesel refineries;
- NRG Chemical Engineering signed a US$1.3 billion deal with state-owned Philippine National Oil Co. in May 2007, and this joint venture where NRG Chemical Engineering has a 70% stake, will include the construction of a biodiesel refinery, two ethanol distilleries and a US$600-million investment in jatropha plantations covering over 1 million hectares, mainly on the islands of Palawan and Mindanao (*Seedling*, July 2007, p. 34-35).

D1 Oils, based in the United Kingdom, is the world's leading developer of jatropha biodiesel. Although its biodiesel refinery in England relies mainly on soybean oil from Brazil, it is expected to switch to jatropha oil from its own plantations. D1 Oils' jatropha plantations are located in Saudi Arabia, Cambodia, Ghana, Indonesia, the Philippines, China, India, Zambia, South Africa and Swaziland. In most cases, the plantations or contract growing arrangements are managed by D1 Oils' local partners, such as the Williamson Magor Group, India's largest tea plantation company, or the Philippine National Oil Company. With the latter, it has a joint venture for the operation of a 1,000-hectare jatropha mega-nursery (*Seedling*, July 2007, pp. 34-35).

D1 Oils is working on the development of high-yielding jatropha varieties, with much of the breeding work focusing on India. In 2005, D1 Oils had contracted India's Labland Biotech to produce about 100 million high-quality jatropha clones through tissue-culture techniques. In 2006, the company hired one of the world's most prominent corporate biotechnology plant breeders, Henk Joos, to lead its jatropha breeding programme. According to this specialist, "the challenge lies in identifying and developing the most promising wild varieties of jatropha and producing hybrids with enhanced yield, higher oil content, and drought resistance characteristics" (*Seedling*, July 2007, pp. 34-35).

Executives from the United States-based company Xenerga Inc. stated they had patented a Malaysian variety of high-octane jatropha, expected to be commercially produced in 2007. Xenerga and its associate company, German-based EuroFuelTech, also manage jatropha plantations in Kenya, where hundreds of thousands of hectares are available for production (*Seedling*, July 2007, pp. 34-35).

Future research and development plans

The Sardar Swaran Singh National Institute of Renewable Energy (SSS-NIRE) was being set up in Punjab for research on bioenergy and synthetic fuels. The Department of Biotechnology within India's ministry of science and technology has set up a Centre for Energy Biosciences in Mumbai for developing cutting-edge biofuels for transportation. Research partnerships brought together the Mahyco Research Centre and several research institutes. At the same time, India's Petroleum Conservation Research Association had set up a National Biofuel Centre at its corporate office and, in order to encourage the production and use of agrofuels, it offered annual awards, based on credit points, to organizations for a variety of activities linked to biofuels. The overall Indian government's ambition has been spelled out by the minister for science and technology and earth sciences on 3 January 2008: "We also have about 63 million hectares of wasteland, of which about half has been earmarked for tree plantation.... But we need to do more research and development on genetically modified jatropha varieties with still higher oil content and devise optimal processing technologies.... Also, we have the ability to completely rewrite the geopolitics of oil if we ensure that the efficiency of transportation in the country – specifically diesel transportation – is improved and bio-diesel substitution takes place on a war footing (from a keynote address delivered at the inauguration of the 95th Indian Science Congress, Andhra University, Visakhapatnam; *Seedling*, April 2008, pp. 15-23).

Critics of this development do not suggest that crops used to produce biofuels are inherently bad. There are many examples in India that show that growing jatropha and pongamia can be very useful. But this is the first time these crops have been promoted for large-scale, commercial production. Some balances (environmental, socio-economical) could be upset at that unprecedented scale, and sound social, technical and economic audits could help to make appropriate decisions. It is true that the Indian government is using a wide range of instruments – welfare schemes, village microfinance, poverty alleviation programmes, agricultural research systems, rural extension services, etc. – to make biofuels a successful venture. There are good reasons for that. It is also important and reasonable to assess the costs and benefits for all the stakeholders, including small and poor farmers [Ram Mohan et al. (2006); Wani et al. (2006)].

China

Although China is the world's third-biggest producer of ethanol, a little is used as fuel. Most spending in the renewable energy sector goes to hydro, solar and wind energy, with less investment in agrofuels because of concerns over impacts on domestic food supplies. Yet, the government has set ambitious long-term targets for the use of agrofuels and has already mandated a 10% blend of ethanol with gasoline for certain provinces and cities. For the time being, despite the construction of ethanol plants during the five-year plans, the demand of ethanol necessary for achieving a 5% blend with gasoline supersedes the supply. State subsidies for agrofuels are mainly channelled to four large ethanol plants: Jilin Fuel Alcohol Company Ltd, Anhui Fengyuan Petrochemical Ltd, Henan Tianguan Group and Heilongjiang Huarun Jinyu Ltd. In addition, a growing number of agrofuel operations are sprouting up throughout the country, many of them backed by foreign investment and oriented towards exports (Ernsting, 2007).

China National Cereals, Oils and Foodstuffs Import and Export Corporation (COFCO) is involved in three of China's four major state-subsidized agrofuel refineries. It owns the Heilongjiang ethanol refinery and has a 20% stakes in the Jilin refinery – the largest in the world in 2007 – owned by PetroChina, and the Anhui refinery. In 2007, it was building a cassava-derived ethanol factory in Guangxi and two maize- and sweet potato-derived ethanol plants in Hebei and Liaoning (Ernsting, 2007).

China National Offshore Oil Corp (CNOOC) was developing a biodiesel refinery and jatropha plantations covering 33,000 hectares in Sichuan in 2007. Outside China, it had a US$5.5-billion joint venture project for palm-oil diesel and sugar-cane or cassava-derived ethanol in Indonesia, and a Malaysia-based joint venture with BioSweet (Malaysia) to build a 1.5-million-ton-per-year palm-oil biodiesel refinery on China's Hainan Island (Ernsting, 2007).

Thailand

In 2003, the government of Thailand mandated a 5% blend in five states and fixed the price of ethanol below that of gasoline. A nationwide mandate for a biodiesel blend of 2% was to come into effect in 2008. National bioethanol production uses sugar-cane and cassava, while biodiesel largely uses palm oil. Thai ethanol companies are complaining that the profit margin is narrow, with low ethanol prices and high feedstock prices (Ernsting, 2007).

Thailand and Brazil agreed on an ethanol technology transfer deal involving the import of 300,000 liters of Brazilian bioethanol. Khon Kaen Alcohol, Thailand's only publicly traded sugar company and one of its biggest ethanol producers, expanded into Laos, where wages were only a quarter of the level of Thailand, through a joint-venture sugar plantation and ethanol refinery that will export to Thailand. On the other hand, state-owned gas company PTT is the largest biodiesel producer in the country; it planned to expand its capacity to 1.2 million liters per day through three joint ventures with local palm-oil companies, including a joint venture with agribusiness giant corporation Charoen Pokphand to open new oil-palm lands in the south of the country and to develop a "downstream to upstream" fully integrated biodiesel project, from the planting of seeds to the final sales of the agrofuel (Ernsting, 2007).

Philippines

The Biofuels Act of 2005 mandated an ethanol blend of 5% in gasoline with an option to increase to 10% after the first two years, and a 1% blend of coconut-based biodiesel with a similar option to increase to 2%. It also provided the agrofuel industry with a range of tax and financial incentives and funding programmes (Ernsting, 2007).

State-owned Philippine National Oil Company has a number of joint-venture projects under way with foreign companies, such as Sumitomo of Japan and Samsung of South Korea. It also signed a US$1-billion biofuel deal with Biogreen Energy (Malaysia) for an agrofuel refinery and 1-million-hectare jatropha plantation, as well as a US$1.3-billion deal with NRG Chemical Engineering Pte (United Kingdom), for the construction of a biodiesel refinery and two ethanol distilleries, and a US$600-million investment in jatropha plantations, covering over 1 million hectares, mainly in Palawan and Mindanao (Ernsting, 2007).

On 4 June 2006, the groundbreaking ceremony for the construction of a techno-demonstration farm for hybrid maize at the Sterling Technopark in Silang, Cavite, signalled the start of multimillion-dollar agricultural projects that will contribute much to the enhancement of Philippine agriculture. The chairman of SL Agritech Corp., a division of Sterling Group of Companies, stated the huge projects, to be financed by the Jelin Fuhua Agricultural Science and Technology Development Co., Ltd. of China, will be managed by the Philippine Fuhua Sterling Agricultural Technology Development Corp. Fuhua Group is a Chinese conglomerate based in Jelin Province in China which in 2006 owned the second largest maize processing facility in the world.

The multibillion-dollar agreement called for the massive production of hybrid maize which was expected to reach some 18 million metric tons after three years and hybrid sorghum which with an annual output of 4.2 million tons. The acreage devoted to hybrid maize was expected to rise from 100,000 hectares to more than a million hectares in the third year. Under this plan, the Fuhua Group intended to build a maize processing plant that will produce 1.76 million tons of milky starch, 600,000 tons of bioethanol, 1.77 million tons of fibre feed, 62,200 tons of maize protein, 39,400 tons of maize oil and 260,000 tons of amino-acids.

Saudi Aramco's subsidiary in the Philippines, Petron, the country's largest oil refiner, has an exclusive ethanol supply agreement with San Carlos Bioenergy, a joint venture between UK-based Bronzeoak and Zabaleta & Co., which is controlled by the president of the Philippines Sugar Millers' Association. In January 2007, the Philippines government signed several agrofuel deals with Chinese corporations, including a US$3.83-billion deal with the Fuhua Group to set aside over 1 million hectares of lands for the production of bioethanol for export to China.

South Korea

In 2006 the government removed tax on biodiesel and mandated that domestic diesel should contain 0.5% biodiesel. However, as gasoline is the fuel most commonly used for transportation in the country, this had a limited impact. Given that South Korea is a major producer of MTBE, which ethanol commonly replaces, the government has shown little interest in promoting ethanol as an agrofuel. Imgen Company planned to build a bioethanol plant in Indonesia's Lampung province that was to be supplied by cassava from a 200,000-hectare plantation. In this same part of Indonesia, Samsung planned to invest US$1 billion in agrofuel projects through a joint venture with palm-oil producer Mapoli Raya and chemical manufacturer Cho Yang Fine Chemical, which was to set up an ethanol refinery and large-scale cassava plantations. Samsung also planned to set up a 200,000-ton-per-year jatropha biodiesel plant in the Philippines with the Philippine National Oil Company (Ernsting, 2007).

Japan

The Japanese government supports the development of an agrofuel industry through subsidies to its corporations, promotional programmes, and supply deals with major agrofuel-producing countries. In 2005, Japanese companies agreed to invest up to US$2 billion in the Brazilian bioethanol sector. This was followed by a number of corporate deals and finally a bilateral agrofuel agreement between the two countries. The investments included a joint venture between Petrobrás and state-owned Nippon Alcohol Hanbai for the export of ethanol, a joint venture between Mitsui and Petrobrás for the production, transportation and export of ethanol to Japan, a biodiesel joint venture between Marubeni and Brazil's grain and oilseeds merchant Agrenco Group, and another Mitsui ethanol joint venture, this time with the Brazilian sugar trader, Coimex (Ernsting, 2007).

Beyond Brazil, Mitsui is building a large jatropha biodiesel refinery in South Africa and a coconut biodiesel refinery in the Philippines, while Itochu, one of Japan's largest trading companies, planned to build cassava-derived bioethanol factories in Indonesia, Thailand and Vietnam. Honda is working with the National Research Institute of Innovative Technology for the Earth on the development of "cellulosic" ethanol, produced from "soft" biomass, such as rice leaves (Ernsting, 2007).

In the centre of Japan, at Niigata, an non-edible rice species called «Hokuriku 193», was being cultivated on 300 hectares by the end of 2008. The purpose was to produce bioethanol derived from the fermentation of starch of this rice species. One ton of Hokuriku would produce 450 liters of bioethanol, a volume almost equal to that produced from maize starch (480 liters of bioethanol per ton of grain). This experimental programme which has been initiated in 2006, was expected to produce 3,000 liters of ethanol; mixed with gasoline at a concentration of 3% this agrofuel would be distributed by some 20 service stations in the region of Niigata.

Research is also being carried out on bioethonol production from roots and stems of the Hokuriku rice (Pons, 2008).

Bioethanol production not only aims at developing a renewable source of energy, but also to increase the productivity of paddy fields and even save them. Japan's rice production has decreased from 12 million tons to 8.7 millions tons, and 40% of paddy fields have been left as fallow, in order to keep the prices stable. According to the director of the Niigata branch of the Association of farm cooperatives in charge of research on bioethanol, «the production of agrofuel is a means to turn back to production idle paddy fields, that may be ploughed in the case of a major food crisis; if they are abandoned, they could be recovered» (Pons, 2008).

In fact, rice cultivation is highly mechanized in Japan and yields could be easily duplicated and reach up to two tons per hectare, while relying on the range of available rice varieties. However, family farms are too small and could not survive without state subsidies. That is why most farmers have another professional activity (Pons, 2008).

In addition, very high import tariffs (778%) make the Japanese rice market quite «independent» from the international market. However, since 1995 Japan has been importing 780,000 tons of rice per year, in order to comply with the minimum regulations of the World Trade Organization. This imported rice is not easy to sell because Japanese consumers prefer the locally produced round grains of rice to the long grains of Thai rice. Part of it is used to feed livestock and another part is stored (stocks were estimated at 2.6 million tons in 2008). Consequently Japanese consumers pay a high price for their rice (one ton cost four times that of Thai rice in 2008), but seem to be satisfied with that situation. It is true that if Japan really opens its domestic market, many farms would be wiped out, because they could not compete in terms of price with Thai or Vietnamese rice (Pons, 2008).

Malaysia

This country has expanded oil-palm plantations to 4.17 million hectares in 2006, with the fastest increase in Sarawak and Sabah on the island of Borneo or Kalimantan. The country is the world's biggest producer and exporter of palm oil, with a 45% share in global palm-oil production, compared to Indonesia's 39% – the world's second biggest producer. Global palm-oil production rose from 4.5 million tons in 1980 to 20.9 million tons in 2000, and it was expected to reach 30.6 million tons by 2010. Malaysia and Indonesia produce 75% of world palm-oil, the price of which has increased from US$500 per ton at the beginning of 2006 to US$1,250 per ton at the end of March 2008 (*Spore*, CTA, August 2008, n° 136, p.4).

Malaysia's per hectare yields are about twice as high as Indonesia's, and production is more intensive, with the use of large-scale cloning of the oil-palm varieties, the heavy reliance on fertilizers and pesticides (Ernsting, 2077).

By the end of 2005, Malaysia had 58 licensed agrofuel investors, the largest of which being the Malaysian companies Golden Hope, IOI Corporation, Kulim and Carotino. In the United States, Imperium Renewables was building the first large biodiesel refinery in 2007 in order to handle huge amounts of palm oil from Malaysia, while Australia opened its first palm-oil biodiesel refinery in November 2006 (Ernsting, 2007).

Indonesia

It intends to overtake Malaysia, as it plans over the next 20 years (2006-2025) to increase palm-oil production 43-fold, with the area under cultivation expanding from 6.4 million hectares in 2006 to 26 million hectares in 2025. Plans for large-scale sugar-cane and jatropha plantations, also for agrofuels, were also being drawn. But the expansion will depend on the global biodiesel market, which is the main driver of palm-oil prices (in addition to the increase in palm-oil demand as food).

In 2007-2008, high palm-oil prices were promoting investment in oil-palm plantations, mills and biodiesel refineries, and the government kept granting new concessions for large areas of land in response to high biodiesel demand and crude palm-oil prices. On 16 August 2006, the president of Indonesia made the commitment to provide US$110 million to small farmers for the plantation of oil-palm and other crops aimed at producing agrofuels. The national effort geared towards the global biodiesel market aimed at creating thousands of jobs in the palm-oil industry that already employed over 1.5 million people in 2007. The skyrocketing price of oil in the first half of 2008 made biodiesel derived from palm oil a profitable economic venture.

About one third of oil-palm plantations in Indonesia are held by smallholders, and the government's expansion plans foresaw a scheme by which a large plantation will lie at the centre of each production unit, surrounded by a large number of much smaller plots (Ernsting, 2007).

Important investors in palm-oil biodiesel are the older Indonesian Bakrie group, and large Malaysian and Singaporean companies, such as Wilmar International. In May 2007, the China's National Offshore Oil Corp (CNOOC) announced plans to build three biodiesel refineries in West Kalimantan. Multinational corporations such as Archer Daniels Midland (ADM) and Cargill are also investing directly in South-East Asia, while energy companies such as Shell, Neste Oil, Greenergy International and BioX Group are either entering into partnerships with other palm-oil biodiesel companies or, as is more often the case, importing large quantities of South-East Asian palm oil. The sector is attracting venture capital, with fund holders such as the Carlyle Group and Riverside Holdings making multi-billion-dollar investments in biodiesel companies which want to import crude or refined palm oil for biodiesel. Both the World Bank and the Asian Development Bank have expressed their keen interest in funding agrofuel production (Ernsting, 2007).

The main markets for palm oil for biodiesel are China and Europe. India continues to be among the three main palm-oil importers, though it prefers home-grown jatropha to imported feedstocks for agrofuels (Ernsting, 2007).

Environmental impact

Oil-palm plantations are expanding quickly on the 20 million hectares of peat lands existing in South-East Asia, particularly in Borneo (Kalimantan). The environmental impact of such an expansion has been considered disastrous by many specialists. Drainage of these peat lands, drying and burning of peat produce huge amounts of carbon dioxide. If these emissions were accounted for in official statistics, Indonesia would rank third among emitters (behind China and the United States), rather than 21st, as placed in 2007. Large-scale peat drainage started in 1996 with the Mega Rice Project in central Kalimantan and continued with the expansion of timber and oil-palm plantations.

Once an area is drained, peat begins to oxidize and to emit carbon dioxide into the atmosphere; at the same time, the peat desiccates and can ignite during the dry season. In 1997 and 1998, fires raged through 6% of Indonesia, scortching 11.7 million hectares of land. During these fires, Indonesia's peat released into the atmosphere a huge amount of carbon dioxide, equivalent to 16%-20% of global fossil fuel emissions those years. Just 55% of Asia's peat lands remained undrained in 2007-2008, and it seems that oil-palm plantations will encroach on them rather quickly.

Specialists highlight that once peat oxidation is complete, no soil will be left and soil erosion can be accelerated, especially in mountainous areas (Ernsting, 2007).

According to Ernsting (2007), the United Nations Environment Programme (UNEP) has warned that, within 15 years, 98% of Kalimantan's and Sumatra's rainforests would have been destroyed. The total number of people living in classified "State Forest Areas" in Indonesia could be as high as 90 million, and of these, according to Watch Indonesia, some 45 million depend on the rainforests for their food and livelihoods. The Indonesian government expected that palm-oil expansion for biodiesel production would create up to 5 million jobs, a figure that Watch Indonesia estimated too high, and would not totally compensate for the loss of income and food inputs due to the destruction of rainforests (Ernsting, 2007).

Environmentalists and Indonesian non-governmental organizations (NGOs) have underlined that land appropriation for oil-palm plantations was generating conflicts and depriving local communities and indigenous people of their communal lands and traditional livelihoods. In particular, these people have to buy rice on the domestic market, putting further pressure on the country's rice supply (Ernsting, 2007).

The controversy was extended to the competition between cooking oil and agrofuel derived from palm oil. According to Setara Jambi, an NGO that campaigns on palm-oil issues in Jambi province of Indonesia, the price of cooking oil has increased from 6,500 rupiah per kilogramme up to 9,000 (i.e. US$1). It was therefore becoming difficult for poor people to purchase cooking oil. Some local companies, such as potato chip manufacturers were facing bankruptcy. The government reacted by selling cheap cooking oil. It also requested giant companies, such as Wilmar International, PT Perkebunan Nusantara, PT Smart TbK and PT Musim Mas, that they must provide 150,000 tons of palm oil each month to meet the cooking-oil needs of the population. Sometimes, companies tended to privilege export of palm oil because of the more advantageous prices, and consequently the local market is not supplied as it should be (Ernsting, 2007).

Conservation groups strongly reiterated that the destruction of rainforests for planting oil-palms could wipe out species like the orangutan, and they have mounted campaigns to boycott palm-oil products. But many locals who depend on palm oil for their livelihood are unhappy about these attacks on the industry. Princeton's ecologist Lian Pim Koh has suggested that environmentalist groups should buy shares in plantations and use profits to buy forested land for nature reserves. These groups, however, stated that ownership would undermine their credibility and they would prefer that the industry invests in forest conservation.

The controversy on the expansion of oil-palm plantations for biodiesel production and its detrimental effects on the rainforest environment and livelihood of people living in and from these ecosystems, has led in Europe, particularly in the Netherlands – the biggest palm-oil importer – to proposals that ranged from a total ban on palm-oil import (which was rejected by the European Parliament and the European Commission), via mandatory certification with the possibility of selective import bans, suggested by the Dutch Cramer Commission, to the mere self-reporting requirement promoted by the United Kingdom's Low Carbon Vehicle Partnership (Ernsting, 2007).

In fact some palm-oil refineries and biodiesel plants were closed down in the Netherlands to respond to the demands of environmentalists; but they were reopened when the Indonesian government explained its position, i.e. that oil-palm expansion was also a means to struggle against poverty. It was also explained that in the future intensification in mature plantations, as it was done in Malaysia, would be preferable to the encroachment on rainforest ecosystems.

At the international level, the Roundtable on Sustainable Biofuels, in consultation with industry, was drawing up "standards", the main proposal being to divert production away from primary forest to "degraded wastelands" – or to logged forest. These standards, inadequate as they may be, would have to rely on the collaboration of corporations like Sinar Mas and Raja Garuda Mas, which had in the past broken agreements aimed at protecting national parks and so-called "high conservation value forests" (Ernsting, 2007).

Transnational biodiesel webs in Malaysia, Indonesia and Singapore

In Malaysia, Singapore and Indonesia, companies involved in the production of palm oil, its transformation into biodiesel and its trade (within and outside the country) are merging, buying others out and forming all kinds of alliances to take advantage of the booming market and the new opportunities. For instance, by the end of 2006, the three leading Malaysian palm-oil companies controlled by the state investment holding company Permodalan Nasional Bhd (Golden Hope Plantations, Sime Darby and Kumpulan Guthrie) merged to form Synergy Drive, the world's biggest listed oil-palm company. The latter could thus control 526,000 hectares of oil-palm plantations in Malaysia and Indonesia and was involved in several planned biodiesel factories (*Seedling*, July 2007, pp. 16-17).

In Indonesia, Tanoto's Pt Asianagro company (Sukanto Tanoto is the owner of palm-oil, forestry and energy corporation RGM International, and one of the richest individuals of the country) has been investing its profits into the construction of a 150,000-ton-per-year biodiesel refinery. Another giant, the Bakrie Group, was building a new US$25-million biodiesel factory, and expanding its plantations to supply the feedstock. Similarly, Indonesia's Surya Dumai Group was constructing its own US$30-million biodiesel refinery. For all these major producers, a key objective is to expand and integrate refining capacity both at home and abroad. By early 2007, the Federal Land Development Authority (FELDA), the largest palm-oil manufacturer in the world, purchased US-based Twin Rivers Technologies, which was operating the US largest biodiesel processing facility (*Seedling*, July 2007, pp. 16-17).

Malaysia's IOI Corporation took over Unilever's European palm-oil processing operations, bought up two Malaysian palm-oil refinery companies and then publicly acknowledged its intentions to take over Asiatic Development, another major palm-oil producer and refiner. In 2007, IOI was constructing a 200,000-ton-per-year biodiesel refinery in Johor, Malaysia and Europe's largest palm-oil refinery in Rotterdam, with a capacity to refine 900,000 tons a year into cooking oil or biodiesel (*Seedling*, July 2007, pp. 16-17).

The Kuok Group has a similar expansion policy. By early 2007, Robert Kuok from Hong Kong, probably South-East Asia's richest individual, brought the various segments of his palm-oil interests under a single entity. The new company, Wilmar International, was formed through a US$4.3-billion merger between Kuok's PPB Oils and Wilmar, which involved not only the Kuok family, but also ADM and China National Cereals, Oils and Foodstuffs Import & Export Corporation (COFCO), China's largest food company and one of its most aggressive investors in agrofuel production. Through the merger, ADM becomes Wilmar International's second largest shareholder (*Seedling*, July 2007, pp. 16-17).

Wilmar International held around 435,000 hectares of oil-palm plantations and 25 refineries in Indonesia, Malaysia and Singapore. Through its alliance with ADM, it had a 300,000-ton-per-year biodiesel refinery in Singapore, and both companies had another three refineries in Riau, Indonesia, each with a capacity of 350,000 tons per year, as well as a refinery in Rotterdam with a capacity of 1 million tons per year, making Wilmar one of the largest biodiesel producers in the world. The company, through its Malaysian subsidiary Josovina, expected to become the exclusive palm-oil supplier to Global Bio-Diesel, a 500,000-ton-per-year biodiesel operation being set up in Malaysia by the South Korean company Eco Solutions (*Seedling*, July 2007, pp. 16-17).

The Singaporean consortium including a trader, Olam, and Wilmar International in association with the West-African leading group of palm oil SIFCA (of Côte d'Ivoire), were planning to invest over US $200 million in oil-palm plantations and processing plants, mainly in Côte d'Ivoire, which will become the supplier of palm oil for West Africa. In addition, the Asian consortium intended to carry out a similar operation in Nigeria where annual production amounted to 800,000 tons in 2007, compared with 300,000 tons for Côte d'Ivoire (*Spore*, CTA, August 2008, n° 136, p. 4).

In sub-Saharan Africa, indeed, palm-oil consumption is increasing steadily while production is stagnating. The continent is therefore dependent on imports from South-East Asia. The palm-oil deficit has been estimated at about 500,000 tons per year for the West African States Economic Community (CEDEAO). In Central Africa, even Cameroon which is the biggest palm-oil producer of the region, must import the commodity; in 2008, consumption was estimated at 250,000 tons, while production amounted to 200,000 tons (*Spore*, CTA, August 2008, n° 136, p. 4).

Since he first ventured into the sugar business in the 1950s, Robert Kuok has steadily expanded the global reach of his operations. In the 1970s, together with the Salim Group, he established Indonesia's largest sugar plantation and became the main supplier to the government. Then, in 1987, R. Kuok, through his Singapore-based Kerry International, purchased a 30% share of the French sugar company Sucres et Denrées (Sucden), that controlled about 15% of the global sugar trade. Later on, Kuok, through his individual holdings and through Sucden, Kuok became a major shareholder in Cosan, Brazil's giant sugar processor and bioethanol producer (*Seedling*, July 2007, pp. 16-17). See pp. 63-64.

Cargill, the Minneapolis-based agribusiness corporation, is operating two palm-oil refineries in Malaysia and a crushing plant in Indonesia. It also boosted the capacity of its Rotterdam plant to refine tropical oils – an additional 200,000 tons per year of coconut oil and 300,000 tons per year of palm oil. On the production side, Cargill launched its first palm-oil plantations in Sumatra in 1997. Then, in 2005, Cargill and Temasek Holding, a private investment arm of the Singapore government, acquired the CDC Group's palm plantations in Indonesia and Papua New Guinea. These included a plantation in Kalimantan and a majority shareholding in four other plantations in the region – three in Indonesia and one in Papua New Guinea. Cargill's existing plantations were merged into the new joint venture, registered in Singapore as CTP Holdings, with Cargill as its majority shareholder assuming complete managerial and operational responsibilities (*Seedling*, July 2007, pp. 16-17).

Experts consider that the demand for biodiesel is fostering consolidation in the palm-oil sector and a shift to transnational webs between foreign companies and palm-oil producers and suppliers, e.g. (*Seedling*, July 2007, pp. 16-17) :

Producer/supplier	Foreign partner	Project
Golden Agri-Resources (Singapore/ Indonesia, owned by the Sinar Mas Group)	China National Offshore Oil Corp and Hong Kong Energy Ltd.	US$5.5 billion, eight-year project to develop crude palm oil-based biodiesel, and sugar-cane or cassava-derived bioethanol on around one million hectares of land in Papua and Kalimantan, Indonesia.
PT Mopoli Raya (Indonesia, subsidiary of the French Bolloré Group)	Merloni (Italy, owned by Indesit/ Fineldo)	Building a 250,000 ton-per-year biodiesel plant in Kuala Tanjung, North Sumatra, called Nusantara Bio Fuel.
Kulim (Malaysia, owned by the Johore Corporation)	Peter Cremer Gruppe (Germany)	Launched a joint venture for the construction and operation of two biodiesel plants in Malaysia and Singapore.
IOI and Golden Hope Plantation (Synergy Drive)	BioX Group (Netherlands)	In 2006, BioX signed a 10-year supply agreement with IOI and Golden Hope Plantations. Deal with IOI include the construction of a biofuel power plant at IOI's refinery in Rotterdam. BioX Group also had joint ventures with Tradewinds Plantations and Sime Darby for carbon trading projects at their oil palm refineries.

BUSINESS AND CORPORATE ALLIANCES IN AGROFUEL PRODUCTION AND DISTRIBUTION

Big agribusiness, oil and finance corporations are among the major players and key investors in agrofuel production, processing and distribution. Thus a number of transnational corporations such as ADM, Cargill, China National Cereals, Oils and Foodstuffs Import & Export Corporation, Noble Group, DuPont, Syngenta, ConAgra, Bunge & Born, Itochu, Marubeni, Louis Dreyfus, are the main backers. In the case of sugar – the feedstock for the production of bioethanol – one could cite British Sugar Tate & Lyle, Tereos, Sucden, Cosan, AlcoGroup, EDF & Man, Bajaj Hindusthan, Royal Nedalco; in the case of palm oil for biodiesel production, IOI, Peter Cremer, Wilmar; and for forestry, Weyerhauser and Tembec (*Seedling*, July 2007, pp. 10-15).

Big oil companies such as British Petroleum, Eni, Shell, Mitsui, Mitsubishi, Repsol, Chevron, Titan, Lukoil, Total, Bharat Petroleum, PT Medco, Gulf Oil, are making investments. So too are those oil corporations more directly linked to their home government's agrofuel agendas, such as Petrobrás of Brazil and PetroChina and smaller firms like PT Medco of Indonesia and the Philippines National Oil Company (*Seedling*, July 2007, pp. 10-15).

Financing is also coming from the world of finance and banks such as Rabobank, Barclays, Société Générale, and from equity funds, such as Morgan Stanley and Goldman Sachs. Then there are the billionaires. George Soros bought the Argentine company Pecom Agribusiness in 2002, which gave him over 100,000 hectares in Argentina for beef and dairy cattle, soya, maize, wheat, rice and sunflower production. Then, in 2004, Soros' company, now called Adenco, expanded into Brazil, where it bought 27,000 hectares of land in the States of Tocantins and Bahia for the production of cotton and coffee. In 2006, Adenco formed a partnership with Brazil's Vieira family, a coffee-growing group from Minas Gerais State, to set up a mill with a productive capacity of one million tons of sugar-cane per year. The group continued to expand and its four sugar processing plants in Brazil will mill 12 million tons of sugar-cane, converting much of it into bioethanol. In the United States, Soros announced that his company was constructing a plant for the production of bioethanol from 50 million tons of maize harvested from an area of 50,000 hectares (*Seedling*, July 2007, pp. 10-15).

Goldman Sachs, one of the world's largest investment banks, not only handles the financing for many of the major agrofuel ventures, but is also one of the leading investors in renewable sources of energy, having invested upwards of US$1 billion already, with much of it going into agrofuels. It co-owns Iogen, a leading "cellulosic" ethanol developer, as well as the energy distribution companies Kinder Morgan and Green Earth Fuels, which are working together on a 86-million-gallon biodiesel plant and storage terminal in Texas that can handle 8 million barrels of biodiesel (*Seedling*, July 2007, pp. 10-15).

Agribusiness corporations tend to sell food and feed rather than agrofuels, due to the steep rise in food and feed commodities in 2008. Cargill, for instance, has openly stated its preference for selling food and feed, because it can make more profits. ADM may be the world's biggest ethanol producer, but its main business still comes from converting maize into animal feed or into high-fructose corn syrup for companies like Coca-Cola and Pepsi Co. These big agribusiness corporations can increase their overall business while selling agrofuels, but they want to control and coordinate the whole process (*Seedling*, July 2007, pp. 10-15).

Other companies are launching production in geographic areas where agribusiness is less present and where production costs are low. Several Chinese corporations struck deals in the Philippines and Indonesia by early 2007 to convert 1 million hectares in each country to the production of agrofuel crops for export. The Maple Corporation, a US energy firm, has set up a sugar-cane plantation and ethanol plant in Peru to take advantage of the country's low production costs and favourable ethanol export access to the United States (*Seedling*, July 2007, pp. 10-15).

In research and development, both big oil companies and biotechnology corporations are channelling their investments in the development of technologies aimed at producing ethanol from cellulosic materials, i.e. enzymes, genes, bioengineering processes. At the same time, funds are increasingly going into the building of fully integrated agrofuel networks, involving production, shipping, processing and distribution. Low-cost countries or regions of production are privileged, e.g. Brazil for sugar-cane or Indonesia for palm oil, and also special deals are made in countries that have preferential trade access to the United States (e.g. Central America and the Caribbean), Japan or the European Union. Consequently, agrofuel projects are generating new alliances or expanding existing ones between local producers and suppliers of the feedstock and foreign corporations/investors (*Seedling*, July 2007, pp. 10-15).

"CELLULOSIC" ETHANOL

In his 2007 State of the Union address, the US president stated in order to improve US energy security his government intended to make “cellulosic” ethanol, i.e. ethanol made from the rougher and woodier parts of plants, a competitive fuel within six years (Sanderson, 2006).

Most plants put the bulk of the energy they store up from the sun into cellulose and hemicellulose and woody plants add another substance, lignin, to the mix. Cellulose makes up the plant cell walls and, like starch, is a polymer of hexoses, while hemicellulose is a polymer of xylose (xylan) and other sugars as well. Cellulose and hemicellulose are much more plentiful than starches and sugars, but they are harder to dismantle.

Enzymatic depolymerization

The most expensive part of making ethanol from lignocellulose is pretreating the biomass to make it accessible to the enzymes that will degrade the polymers into sugars that can be fermented into ethanol. Typical pretreatments reduce the feedstock’s volume chemically using acids, peroxides and ammonia, often along with some form of mechanical pressing or shredding. The tailoring of chemical and physical pretreatments for specific biomass resources is a field of growing interest and practicality. The objective of research is to develop pretreatment technologies that involve fewer chemicals, require less energy and do not degrade the sugars that are set free in the process (Sanderson, 2006).

A further objective is to concentrate on enzymes for degrading cellulose. Research efforts have reduced the cost of cellulase by a factor of 5 to 10. Future cost reduction in bioprocessing will be accomplished by combining cellulase/hemicellulase treatments with other steps. For instance, researchers have proposed combining cellulase production with the fermentation steps via modified micro-organisms capable of both cellulase production and ethanol fermentation which could provide just-in-time delivery of the optimal mixture of the hydrolytic enzymes (Sanderson, 2006).

Abengoa Bioenergy of St Louis, Missouri, a subsidiary of the Spanish engineering group Abengoa, invested US$10 million in Dyadic International, a biotechnology company that is concentrating on enzymes for degrading cellulose. Based in Jupiter, Florida, Dyadic did not start out as an energy company, in the 1970s: it was a leading supplier of pumice for stone-washing jeans. The enzymatic expertise developed by the company was used to isolate fungi that break down wood. Starting from a filamentous fungus discovered by accident in a Russian forest, ten years of processing and genetic engineering led to Dyadic's patented C1 fungal cell system. The fungus genome has been fully sequenced and induced to overexpress the genes that then control the production of cellulases and xylanases (Sanderson, 2006).

Genetically engineered crops

Exogenous depolymerization enzymes used in the bioethanol production process could be replaced with plants that are capable of synthesizing those enzymes in situ. For instance, Ceres, a biotechnology company based in Thousand Oaks, California, and other companies including Edenspace Systems in Dulles, Virginia, are engineering crops to produce enzymes that would break down their own cellulose when triggered. Carbohydrate depolymerization enzymes, such as cellulase, could be triggered when an inducer is applied to the plant. A signal sequence from a cell wall protein could be spliced onto the cellulase gene to ensure that the cellulase synthesized by the plant is localized to the plant cell wall. The cellulase signal sequence-coding region would be attached to a chemically induced promoter that would switch on the cellulase gene. Once the modified cellulase transgene is introduced into a host plant, seeds could be produced, planted and cultivated normally. Just before the harvest, the crop would be sprayed with the chemical inducer. The cellulase would then be produced and transported to the cell wall, where it would start to break down the cellulase. After harvesting, the residual plant material would be collected and transported to a biorefinery, during which the in situ generated cellulase would continue to depolymerize cellulose to glucose. An added feature to this approach is that additional depolymerization enzymes could be brought to bear for further no-cost conversion of plant polysaccharides to mono or oligosaccharides, facilitating subsequent separation or fermentation operations (Schubert, 2006).

Polyculture

As Thomas Faust, biofuels research manager at the US National Renewable Energy Laboratory in Golden, Colorado, pointed out, the fundamental trade-off is between processing and environmental impact. "If one is going to genetically engineer a plant with desirable characteristics, a monoculture makes a lot of sense. From a conversion perspective, the ideal feedstock would be very homogeneous, a single grass, with constant moisture, available all year round. But to have a truly ecological environment-friendly option, mixtures would be preferable". David Tilman, an ecologist at the University of Minnesota in St Paul, thinks that mixed planting might be the way to obtain biomass as a renewable energy crop that would not compete with food or affect commodity prices. Experimental plots containing mixtures of prairie plants yielded 2.7 times as much biomass on average, even outperforming the highly touted energy crop switchgrass. This is important because the more there is of biomass – at least in theory – the more fuel can be extracted from it. A polyculture approach means finding the right mix of plants for lots of different conditions. On the other hand, especially with technologies not yet fully developed, agrofuel producers would prefer a uniform feedstock, which means plantation of predictable, well characterized plants – poplars, perhaps, in wetter climates, switchgrass or miscanthus, also known as elephant grass, in drier and warmer regions.

Compared with maize, switchgrass cultivation requires less fertilizers and water, and results in one-eighth the nitrogen runoff and one hundredth the soil erosion, according to the US Department of Energy. And with current technology, switchgrass could yield roughly 3,100-7,600 liters of ethanol per hectare (greenhouse-effect gas savings are estimated at 37%-73%, most studies indicating 65%-70%, versus petrol). Comparatively, maize stover would produce 1,100-2,200 liters of ethanol per hectare, and greenhouse-effect gas savings are estimated at 60%-100% (vs petrol). In the case of elephant grass, the figures are 7,300 liters per hectare and 65%-70% (vs petrol) respectively; and of poplar, 3,700-6,000 liters per hectare and near 100% (vs petrol) [Schubert, 2006]. See also Hazell and Pachauri (2006).

Boosting biomass

Ceres' work aims at both enhancing the biomass produced and reducing the inputs needed, producing a crop that flourishes on marginal lands. The company's approach is to identify favourable genes in Arabidopsis. It has found genes that boost biomass, increase nitrogen use efficiency and increase resistance to abiotic stress (drought, cold or salt). Ceres had a US$137-million licensing agreement with Monsanto to characterize such genes for new varieties of traditional row crops such as maize and soybeans. It is also using the genes in molecular marker-assisted breeding programmes for switchgrass and other crops in collaboration with the Samuel Roberts Noble Foundation based in Ardmore, Oklahoma. This Foundation has already increased the yield of switchgrass by 25% using conventional breeding (Schubert, 2006).

Fermentation process

With respect to the fermentation process – the second key aspect of ethanol production after biomass production and depolymerization – it is rather inefficient because no wild organisms have been found that can convert a mixture of hexoses and pentoses at high yield into ethanol. However, several groups have made great advances in this field by genetically modifying micro-organisms. This strategy has been effective in adding pentose conversion to *Saccharomyces cerevisiae* and to *Zymomonas mobilis*. The other primary strategy has been to modify a host capable of converting multiples sugars to produce only ethanol from glycolysis. Other remaining microbiological challenges include the need to understand and manipulate ethanol and sugar tolerance and resistance to potential inhibition generated in presaccharification treatments. Solution to this issue will need to accommodate the variability in biomass resources (Ragauskas et al., 2006).

Market and investments

Dyadic International's chief executive, in 2006, believed that the cellulosic ethanol market could eventually be worth US$20 billion a year in the United States and suggested there was enough raw material available in this country to produce 2.4 billion barrels of cellulosic ethanol a year. This is a little more than half of what some estimates claimed was needed to completely replace gasoline as a fuel – the US gets through some 3.3 billion barrels a year, but the energy content of ethanol is lower than that of petroleum (Sanderson, 2006).

In 2006, the leader in the cellulosic ethanol market was Iogen, which used fungal enzymes and produced small quantities of ethanol from straw at its pioneering cellulosic ethanol facility in Ottawa. It is an achievement, but even when it reaches its full capacity, it will produce only 2.5 billion liters (16,000 barrels) a year. Iogen has isolated the right enzymes and developed the right pretreatment systems as well as the yeast systems. The company was looking to build new facilities in Idaho, Saskatchewan and Germany. In 2006, Iogen secured a US$30 million investment from Goldman Sachs bank, bringing the total invested in it since the 1970s up to US$130 million. But not all potential investors are convinced. One reason for this behaviour is that many companies in the sector hide details of their processes and they are therefore hard to evaluate, whether they be relatively small outfits such as Iogen or giants such as DuPont, which is also developing cellulosic ethanol technologies. Robert Wilder, who manages the Wilderhill clean energy index – the first such index to be accepted on Wall Street – agreed, but acknowledged the constraints that the chief executives of small cellulosic ethanol companies worked under in terms of not tipping their hands to larger competitors (Sanderson, 2006).

The sizeable investments being made by agribusiness giant Archer Daniels Midland – the biggest ethanol producer in the United States and a company run by a chief executive who was recruited from the oil industry – are mostly in traditional maize ethanol. The same applied to the British entrepreneur Richard Branson's investments in Ethanol Grain Processors of Tennessee and a new grain-based Californian ethanol venture, Cilion. But there is some evidence that enthusiasm for investing in maize ethanol may be waning (Sanderson, 2006).

This might mean the market was aware that, although subsidies might keep it profitable for the time being, there was no way that maize ethanol could make a market difference to long-term energy use in the United States. To make enough ethanol to start seriously displacing oil imports requires a processs using cellulosic materials such as switchgrass or miscanthus, which provide far more tons of biomass per hectare than maize kernels ever can, and can be grown on land not suitable for conventional agriculture. Other sources could be farm wastes or trees or newly engineered plants. There seems to be an investing impasse: the companies in the business at the moment make money; the ones that might take it to the next stage do not in large part because no one has made the heavy capital investments needed for plants that make use of the technologies that have already been piloted (Sanderson, 2006).

Advanced research

One way out is to invest across the board. This is the strategy pursued by Vinod Khosla, who is one of the founders of Cilion. V. Khosla is also involved in cellulosic ethanol technologies through two companies based in Cambridge, Mass.: Celunol, which started to operate its own plant in 2006, and Mascona, which concentrates on process engineering and which in November 2006 raised US$30 million in second-round venture funding. V. Khosla was also a major investor in Kergy, a company that turns biomass into fuel, using just heat and catalysts (Sanderson, 2006).

There seems to be few people like Vinod Khosla who are interested in investing on enhancing and improving agrofuel production, as many in the industry see the responsibility resting with governments to provide attractive tax incentives. But government's incentives cannot substitute R&D endeavour. Thus pioneering companies welcome increasing levels of basic research from the government, such as the US Department of Energy's pledge of €252 million to set up three new bioenergy research centers, two of them being largely focused on cellulosic ethanol. On the other hand, the European Union has set aside €100 million (US$132 million) for cellulosic ethanol in its seventh Framework Programme for Research (Sanderson, 2006).

BP has announced it will invest US$500 million over ten years to fund an Energy Biosciences Institute, which will be a dedicated facility based at a university. The University of Cambridge, Imperial College (London), the Massachusetts Institute of Technology, Stanford, the University of California, Berkeley and Lawrence Berkeley National Laboratory have all been mentioned as possible hosts. The final decision was expected in 2008 (Sanderson, 2006).

One possibility for such research to pursue is replacing ethanol with another form of alcohol. Ethanol, although easy to produce through fermentation has inherent problems: its tendency to pick up water makes it hard to transport, particularly in pipelines; it is corrosive and is more volatile than one might wish; and its energy density is low compared with regular gasoline. For these reasons, BP and DuPont are working with British Sugar to adapt their ethanol fermentation facility in East Anglia to produce butanol. The plant will use locally grown sugar-beet as the feedstock, but in the long term cellulosic biomass. An industry demand for butanol as an end product could actually increase interest in cellulosic technologies. If oil companies become confident in biofuel technologies, investors would in turn be more confident of the biofuels industry as a whole, giving the industry the boost what it seems to need (Sanderson, 2006).

Robin Zwart of the Dutch Energy Research Centre in Petten hopes that upcoming improvements in efficiency will drive the price of agrofuels down, but stated that oil prices will have to exceed US$70-80 per barrel to make liquid fuels from, for instance, willow trees economical. Carbon taxation or emissions trading would give a boost to biomass-based systems. That is why until biomass supply and technology are scaled up, there is still the appealing option of spiking coal feedstock (to make liquid fuel) with biomass. Coupled with carbon sequestration, this would reduce greenhouse-effect gas emissions without requiring much change to existing technology. According to Robert Williams, a researcher at Princeton University's Environmental Institute, a mixture of 89% coal and 11% biomass, liquefied to produce fuel, could reduce carbon emissions by 19% relative to using the same process with coal only (Ledford, 2006). See also Hazell and Pachauri (2006).

OTHER POTENTIAL (BIO) FUELS

Biokerosene from babassu-palm oil (Brazil)

In 1984, Expedito Parente developed the synthesis of a biokerosene that was used to propel a plane of the Brazilian army over a distance of 900 km. At that time, Brazilian authorities had a marked preference for bioethanol and consequently the development of biokerosene from babassu-palm oil was abandoned. However, in 2005, the United Nations awarded E. Parente and his team, working in Fortaleza, north-east of Brazil, the Blue Sky Award, which annually rewards an innovation in the area of renewable sources of energy. Thereafter, the team was approached by Boeing which signed a scientific and technological cooperation agreement. Some of the research was being carried out by the NASA (National Aeronautics and Space Agency) for Boeing (Castello-Lopes, 2007).

According to E. Parente, the new biofuel would not be approved for commercial use before 2009. A confidentiality clause of the contract signed by him with the US agency and aircraft manufacturer forbade any provision of technical data on current research. It seems, however, that oil from the babassu palm tree which made up a large proportion of the biofuel developed in 1984, is part of the new biofuel, together with other oils derived from tropical plant species. Such production is on tune with the trend towards the steady increase in the output of agrofuels worldwide. For instance, the European company Safran which wants to reduce by 20% the gas emissions by the engines it manufactures with General Electric, has carried out a first trial by mid-June 2007 with a fuel derived from plants (30 %) [Castello-Lopes, 2007].

New fuels for aircrafts

While the global aircraft fleet was expected to double between 2005 and 2025, the steady increase in fuel prices and the need to protect the environment and decrease the emissions of greenhouse-effect gases are inducing the aircraft manufacturers to find news fuels and improve their use in the engines. Thus, in February 2008, Airbus was a forerunner when one of the four engines of its A380 jumbo jet has been using a mixture of kerosene and a liquid fuel derived from gas (GTL or gas to liquid); the plane flew from Filton in the United Kingdom to Toulouse, France. Three weeks later, Boeing flew one of its B747 from London to Amsterdam (Virgin Atlantic Airlines), using a blend of conventional fuel and a mixture of coconut and babassu palm oils. The US manufacturer also flew a small two-seat propelled plane in Spain, using a hydrogen fuel cell (Gallois, 2008).

In addition to building planes that consume less fuel, three possibilities are being envisaged by the researchers and industrialists in substituting, part or totality of kerosene. The feedstocks used for that purpose are fossil energy resources, agrofuels and hydrogen. The fastest way to proceed is to liquefy natural gas or coal, through the Fischer-Tropsch process developed at the beginning of the 1920s by German scientists and used during the second world war. The gas to liquid (GTL for natural gas) or coal to liquid (CTL for coal) can be consumed in aircraft engine without major change of the latter: it is generally blended with ordinary fuel and it could replace it totally. South Africa had to rely on CTL during the apartheid period, when it was deprived of oil, and nowadays CTL represents 30% of its transportation fuel. In order to secure its supplies, the US airforce wants to use such a blend in all its planes by 2011 (Gallois, 2008).

However, these fuels do not reduce the emissions of greenhouse-effect gases. In addition there are few plants that produce them, except those of Sasol in South Africa or that of Shell being built in Qatar. Investments are also very heavy: between US$30,000 and US$100,000 would be needed for the production of a barrel per day of this kind of synthetic fuel according to Paul Kuentzmann, senior adviser at the National Office of Aerospatial Studies and Research of France (ONERA) [Gallois, 2008].

The other possibility that is more environment friendly concerns the second-generation agrofuels, such as those produced from agricultural wastes, wood-industry residues, animal fats and microalgae. According to ONERA, their commercial scale production would become a reality by 2040 only. The last possibility, i.e. hydrogen, liquefied natural gas (LNG) or methane is even more distant because a number of technological hurdles should be overcome (Gallois, 2008).

Nevertheless, the need to act urgently has led the US Commercial Aviation Alternative Fuels Initiative (CAAFI), under the aegis of the Federal Aviation Administration (FAA), to adopt the following time scale:

in 2008, certification of a mixture of kerosene and 50% of synthetic fuel; in 2010, adoption of a fully synthetic fuel; and in 2013, use of an agrofuel (Gallois, 2008).

Biofuels from microalgae

"No other source comes close in magnitude to the potential for making oil from algae", stated Al Darzins, director of the Research Center for Biofuels at the National Research Energy Laboratories of the US Department of Energy. Experts have estimated that algae produced oil yields more than 100 times those of common agrofuels crops such as soybeans, yet required a fraction of the cultivation area. For instance, one acre of maize produces about 81 gallons of bioethanol a year, while oil-palm may produce 650 gallons of biofuel, and algae may yield up to 15,000 gallons (Jimenez, 2007).

Microalgae have been qualified as the third-generation biofuels. According to Juan Wu of the biotechnology consulting firm Alcimed, "large-scale production of biodiesel from microalgae will happen more rapidly than forecast" …"commercialization would be possible in three to six years and the price would be competitive with that of oil-derived diesel". Olivier Bernard, in charge of the French research project Shamash (the name of the Babylonian goddess of sun), who works at the National Research Institute for Informatics and Automation (INRIA) in Sophia Antipolis (south-east of France, near Nice), was more careful: "theoretically, the potential of microalgae is huge and it is justified to devote large resources to this potential source of fuel. But we are still at the level of the laboratory, and large-scale production cannot be envisaged before at least five years, more probably ten years" (Le Hir, 2008).

Researchers have also found they could greatly increase the amount of oil produced using genetic engineering techniques. Genetically modified algae could produce oil yields of 60%-70% compared with the 5%-20% in oil contents of natural algae. In December 2007, Royal Dutch Shell, Europe's biggest oil company, became the latest business to put its faith in algae, announcing that it hoped to build a commercial research plant which it believed would produce biodiesel from algae in two years. Shell admitted at the launch of its venture that it would be a substantial journey to make algae-derived biofuels commercially viable, and technological innovations would be needed. Even then, it added, the economics of algae-based biodiesel would probably have to be supported by tax breaks or incentives that reflected its superior environmental impact compared with first-generation agrofuels (Jimenez, 2007).

Shell took a majority stake in a joint venture, with Hawaii-based HR Biopetroleum, that initially expected to build a small research plant but hoped to move to a full-scale commercial plant of 49,421 acres. Shell stated that the environmental benefits of algae were greatly superior to those of first-generation agrofuels, because algae do not need to be grown on farmland and deforested land, thus minimizing the damage to ecosystems (Jimenez, 2007).

About a hundred projects have been launched in the United States, Australia, China and Israel. In Europe, a dozen of research programmes were being carried out in 2008. One of the pioneer actors, the US company Petrosun, has announced during the spring of 2008 the creation at Rio Hondo (Texas) of a farm of marine microalgae over an acreage of 450 hectares of salt ponds, and thereafter of a second 1,100-hectare farm near the Gulf of Mexico. The Israeli company Algatech which has been manufacturing since 1999 products derived from microalgae for health and food uses in the Negev desert, is now focusing on the production of fuel from microalgae. GreenFuel, a spin-off of the Massachusetts Institute of Technology (MIT), is commercializing cultivation systems of algae. Oil companies such as Shell and Chevron have shown their interest in this new venture (Le Hir, 2008).

Olivier Bernard stressed that microalgal species that accumulate up to 80% of their weight as lipids, under stress such as lack of nitrogen and sudden and heavy increase in light intensity, could be a source of biodiesel. According to Jean-Paul Braud, manager of Innovalg, a company that grows microalgae, 1.5 ha of ponds under greenhouse conditions can produce several tons of biomass per year, even in bad weather conditions. This is considered a great advantage over crops whose limited acreage is a limiting factor in the biofuel economic model. For instance, in France, if all motor vehicles were fueled with biodiesel, oilseed-rape should be grown on the whole area of the country (Roux-Goeken, 2007).

The research programme coordinated by Olivier Bernard aims to design a viable production system. The programme was initiated in December 2006 and funded over three years with €2.8 million. It makes cooperate research centres such as INRIA, the National Scientific Research Centre (CNRS), the Commissary for Atomic Energy, universities, the Overseas Cooperation Centre in Agricultural Research for Development (CIRAD), the French Institute for Oceanographic Research (IFREMER) and a small company, Valcobio (Roux-Goeken, 2007).

The first objective of the project is to identify a microalgal species that grows rapidly and produces the largest mass of liquids. This should not be genetically modified. Several countries, e.g. Germany, China, Spain, United States, United Kingdom and Japan, are already competing in order to find out the appropriate species. Such competition is stimulated by the statement in a 1996 US report that “the use of microalgae as biofuel becomes economically worthwhile when the cost of the oil barrel reaches US$60 to US$70” (Roux-Goeken, 2007).

But the bio-engineering and manufacturing processes are far from being mastered. In addition, one has to select among the hundred thousands microalgal species which are most promising, or to genetically engineer those with faster growth and higher capacity to store lipids. One also needs to compare the competitive advantages of cultivation in salt or sweet water ponds, or in closed photobioreactors that avoid microbial contamination and allow a better control of photosynthetic performance, but are costly. Once the most efficient microalgae are selected, it is crucial to find the most appropriate conditions for fatty acid production, e.g. stress conditions (nitrogen deficiency) and higher concentrations of CO_2. This carbon dioxide could come from energy-generating plants or industrial facilities: about 2 kg of CO_2 per kg of plant biomass would be a good ratio.

Finally, the extraction procedure of oil from microalgae is another challenge, as the current process of centrifugation, drying and extraction by an organic solvent consumes too much energy. Thereafter, the oil should be transformed into biodiesel. It is therefore reasonable to state that much progress in research and development remains to be done before microalgae become a valuable source of fuel (Le Hir, 2008). “The bottleneck in the process is the expensive technology required for algae oil production” according to Ralph Simms, a senior analyst at the International Energy Agency in Vienna. This expert has stated that “in order to be competitive, algal biofuel costs should be cut down to less than that of the bioethanol price” (Jimenez, 2007).

For the time being, algae oil output remains small, with the largest production volume at a few hundred gallons a year, claimed by several US start-up companies working on this technology. But the oil majors and clean technology companies are racing to discover the technology breakthrough. Thus, Don Paul, chief technology officer at Chevron, the US energy company which is also funding a research programme on algae, considers the success of second-generation biofuels depends on collaboration among industry, universities, research institutions and governments. Their collaboration is of primary importance for overcoming the technological and commercial challenges that these products entail (Jimenez, 2007).

Hydrogen produced from cellulose degradation by termites

An international research team led by Falk Warnecke of the Department of Energy Joint Genome Institute (DOE-JGI, Wallnut Creek, California) has published a study on 22 November 2007 on the degradation of cellulose in the digestive tract of termites belonging to the genus *Nasutitermes*. This might help understand how cellulose is digested by these insects and transfer the knowledge to the processes of using cellulose as a biofuel. The termites studied by the researchers were collected in Costa Rica's rain forest, and the genomes of micro-organisms present in the stomach samples of 165 *Nasutitermes* termites have been sequenced. It was found that these genomes mainly belonged to two groups of bacteria: treponemas and fibrobacteria. The researchers also found that 500 genes were involved in the degradation and assimilation of cellulose (Galus, 2007).

Andreas Brune of the Max-Planck Institute for Terrestrial Microbiology (Marburg, Germany) made the following comment: "The tiny digestive tract of termites functions like a bioreactor with an extraordinary efficiency… the microbial environment of termites' digestive tract could theoretically transform a sheet of paper (A4 format) into two liters of hydrogen". He considered that the results obtained by the team led by F. Warnecke were outstanding ones and much remained to be discovered (Galus, 2007).

The US Department of Energy wished to develop industrial bioreactors where the termite biochemical systems would be mimicked to produce hydrogen from wood. Hydrogen will be used in fuel batteries in motor vehicles. Presently, hydrogen is generated from water hydrolysis or from natural gas, a process that consumes large amounts of energy.

Other biofuel alternatives

In 2001, Randy Cortright of the University of Wisconsin developed a process to convert biomass materials into fuels and chemicals - a new catalytic technique called bioforming. He left the university the following year to found the company Virent in order to commercialize his findings. In 2008, Virent could produce small amounts of fuel from stalks, and R. Cortright stated the process would work with wheat straw, sugar-cane stalks and switchgrass. The researcher announced that the company could produce half a gallon (2 liters) of gasoline a day. Clearly there was a scale issue; but the fuel has propreties so similar to petroleum-based gasoline that it could be used to run a car. The Wisconsin-based company, which had 76 employees, hoped to build a bigger pilot plant in 2009, followed by a commercial demonstration plant that could generate 10 million gallons (38 million liters) annually (*Time*, 8 December 2008, p. 45).

Although the bioconversion of polysaccharides to ethanol is among the most developed process technologies available for agrofuels, other chemical technologies offer promising biofuel alternatives. They are centered on the removal of oxygen from carbohydrates to obtain oxygenated hydrocarbons. For instance, controlled elimination of water from sugars has been extensively studied and can provide 5-hydroxymethyl-2-furfural (HMF), levulinic acid, and other organic acids. These materials which are too polar for direct liquid fuel applications could be used as a resource for subsequent conversion to alternative fuels. For instance, controlled decarboxylation and dehydration of hexoses could yield structures such as valerolactone or e-methylfuran, that could be considered as components for novel gasoline blends, which are typically dependent on ~ C5 to C10 hydrocarbons. Rapid progress in catalysis, computational modelling and combinatorial chemistry will lead to a suite of catalytic systems that will facilitate the conversion of biomass polysaccharides to liquid alkanes and oxyalkanes for fuel applications (Ragauskas et al., 2006).

For the biorefinery approach to be widely applicable, the lignin component of lignocellulosic biomass must also be dealt with. Residual lignin from paper pulping is generally burnt for heat and power, but lignin thermal-cracking studies using temperatures of 250°C to 600°C have demonstrated the potential of generating low molecular weight feedstocks for further processing. This pyrolysis approach to biofuels from lignin is also being pursued with biomass in general, with and without a catalyst; it provides about 58% to 77% conversion of biomass into a condensable gas, 13% to 28% noncondensable gases, and 6% to 13% char formation. The condensable gases can be refined to fuels and chemicals, and the noncondensables can be steam-reformed to synthesis gas (syngas), a mixture of CO and H_2, which can also be used to produce fuels and chemicals (Ragauskas et al., 2006).

The Netherlands has carried out a lot of research into the process of gasifying biomass, but only demonstration-scale plants were being operated. Choren, a German company, and Shell were building a commercial plant in Freiberg, which would produce 15,000 tons per year

(110,000 barrels per year) of what Choren calls SunDiesel. Construction of five 200,000 tons per year facilities using wood and agricultural waste was scheduled to begin in 2008. By far the biggest undertaking of its kind to date, the total output from this project would still be enough to supply only about 4 % of Germany's projected diesel made in 2015 (Ledford, 2006).

Biofuel production through "synthetic biology"

The company Amyris Biotechnologies, based in Emeryville, California, was founded in the summer of 2003 by Jay D. Keasling, professor of chemical engineering at the University of California, Berkeley, and director of the synthetic biology department of the Lawrence Berkeley National Laboratory, and three post-doctoral students from his laboratory: Neil Renninger, Kinkead Reiling and Jack D. Newman. They received a large grant, a year later, from the Bill & Melinda Gates Foundation through the Institute for One World Health (the latter received US$42.6 million) to finance the antimalarial drug, artemisine. Amyris engineered bacteria to excrete artemisine, which is very effective against malaria and is extracted from Artemisia annua or sweet wormwood that only grows in China and Vietnam, and costs US$2.40 for a course of treatment – a high price for the world's poor. Amyris' technique would reduce the cost of artemisine to less than US-cents25 for a course of treatment, according to the company (Pontin, 2007). See also The Economist (2006 b).

In January 2006, a presentation by J. Keasling at the World Economic Forum in Davos caught the attention of John Doerr of Kleiner Perkins Caufield & Byers and Vinod Khosla of Khosla Ventures, that Amyris' founders began to consider seriously which other compounds their bioengineered microbes might produce. The two venture capitalists with the private equity group of Texas Pacific Group Ventures, invested US$20 million into novel biofuel production. As a result, over the year 2006, Amyris' researchers have created micro-organisms whose metabolic pathways are yielding alternatives to diesel, jet fuel and gasoline. They try to make the conversion from sugars to fuel more efficient. According to K. Reiling, the company's vice-president for development, "if one can obtain above 90% efficiency, the process is competitive with ethanol and oil" (Pontin, 2007). See also The Economist (2006b).

In order to respond to the worries expressed by environmentalists that the adoption of agrofuels could lead to the diversion of agricultural land from food to biomass production, raising food prices and further harming the environment, Amyris' fuels would be derived from a variety of feedstocks, including switchgrass and jatropha oil, grown on marginal lands that cannot be used for food production. Amyris planned to begin selling biodiesel in 2010, and biofuel replacements for jet fuel and gasoline after that (Pontin, 2007).

THE AGROFUEL CONTROVERSY AND POLEMICS

Maize, sugar and oilseeds for food or for fuel?

Among the causes of the global food crisis that started in 2007, the production of agrofuels has been considered as reducing the area devoted to food crops and decreasing the volume of food commodities, mainly cereals. In addition to questioning their economic, energy and environmental efficiency, agrofuels have been denounced as a threat to food supply. Not only non-governmental organizations have done so, but also politicians have been critical. For instance, the German minister for cooperation and devolopment called for the suspension of agrofuels from cereals until the end of the crisis. On 21 April 2008, the president of Peru stated that agrofuels were at the origin of the current food crisis. At the International Energy Forum in Rome, in April 2008, biofuels were also criticized. Slovenia's prime minister, who was chairing the European Union, stated in April 2008 that the objective of incorporating 10% agrofuels into gasoline by 2020 throughout the Union might be revised (Caramel, 2008a; Clavreul, 2008).

Earlier on, Fidel Castro, in his first article published on 29 March 2007 in several Cuban newspapers (*Granma, Juventud Rebelde*, etc.) since he has been operated on 27 July 2006, stated that "more than 3 billion people worldwide were condemned to a premature death because of starvation or thirst". This statement was issued after it was announced that the US president met with motorcar manufacturers and made a strong plea in favour of biodiesel and bioethanol. F. Castro considered "sinistrous the idea to transform foods into ethanol". He also criticizes those in Cuba who "dream to transform sugar-cane into biofuels". "Lands devoted to direct production of alcohol can be better used to produce foodstuffs for the people". Nevertheless, Cuban sugar refineries have been dismantled to a large extent, without significantly improving food production. Cuba annually imports large quantities of rice, beans, soybeans and chicken from the United States (Paranagua, 2007).

Cuban president's strong criticism was also directed against the agreement signed on 9 March 2007 between the United States and Brazil's presidents in order to develop cooperation for the worldwide expansion of bioethanol production. The reply by Celso Amorim, Brazil's minister of foreign affairs, was clearcut: "F. Castro is rather outdated in this area. He pretended that Brazil's projects for ethanol production would not work. But nowadays, everybody can realize that ethanol is an option to avoid dependence on oil. A world market of ethanol would be profitable for Cuba" (Paranagua, 2007).

According to C. Ford Runge and Benjamin Senauer, two economists: "About 204 kg of maize are needed to produce 94.5 liters of ethanol and fill the tank of a sport utility vehicle (SUV), i.e. enough calories to feed a person for a whole year". The same economists suggested that more research should be carried out on alternative agrofuels. In 2050, to feed 9 billion people, food production should be doubled, while cultivable land will be scarcer. There will be therefore some kind of competition between food and agrofuel production. This may be true for wheat and rice, as foodstuffs, and also for maize, used as food and feed, but less for sugar-cane and cotton (Clavreul, 2007).

Jacques Diouf, FAO's director-general, stated: "Biofuels are both a risk and an opportunity. A risk if they substitute food crops, an opportunity if they provide an additional income to the producers". As recalled by an adviser to Brazil's president: "The world problem is not the lack of food, but the lack of income". (Clavreul, 2007)

Amidst the polemics on agrofuels, Brazil – the world's second biggest producer of bioethanol derived from sugar-cane – has been the focus of harsh criticism, along with the United States, the world's biggest producer of bioethanol derived from maize. For instance, Dominique Strauss-Kahn, director-general of the International Monetary Fund (IMF), stated that agrofuels raised "a real moral issue", while the former special rapporteur of the United Nations Council of Human Rights on the right to food, Jean Ziegler, even spoke of a possible "crime against humankind". The president of France, Nicolas Sarkozy, strongly criticized the "unprecedented fiscal dumping" practised by the United States and Brazil to promote the production of "some biofuels" (Langellier, 2008).

Brazilians, and their president Luiz Inácio Lula da Silva at their head, consider these attacks as unfair and that they are victims of a misinformation campaign as well as of the harsh criticism, probably more justified, addressed to the United States. They indeed claim that there is a difference between the "good" ethanol – theirs – and the "bad" one – that produced by the United States. Bioethanol derived from cane sugar is less costly to produce than gasoline, and one hectare of sugar-cane produces more than the double of bioethanol than one hectare of maize. Cultivation and transformation of maize into ethanol consume seven fold more energy than those of sugar-cane. In addition, the cultivation of sugar-cane and the production of sugar do not deprive humankind of a staple food such as maize. Brazil claims that the cultivation and yields of both cereals and sugar-cane have increased, sugar-cane being grown on only 12% of arable lands. "We fill without problem both stomachs and motor-car tanks" summarized President Lula da Silva, who therefore concluded that accusing bioethanol for threatening food security was "a shameful lie" (Langellier, 2008).

At the 30th regional FAO conference which ended on 18 April 2008 in Brazilia, President Lula da Silva rejected any linkage between the production of agrofuels and the increase in foodstuff prices. Once again he mentioned the reasons for such an increase: adverse weather conditions in grain-producing and exporting countries, demand not met by supply and increase in food consumption in a number of developing countries. "There are many more people that can afford a meal three times a day; Chinese eat, Indians eat, Brazilians eat, and people live longer" he stated (Langellier, 2008). "Don't tell me, for God's sake, that food is more expensive because of biofuels. It is costly because the world is not ready to see millions of Chinese, Indians, Africans, Brazilians and Latino-Americans eating three times a day"... "Biofuels are not the evil products that threaten food security, on the contrary they decrease the dependence on fossil fuels without jeopardizing food supply" he added (Langellier, 2008).

It is true that the growth of bioethanol production from cane sugar has not prevented Brazil to become one of the world's major agricultural products exporter. The expansion of sugar-cane cultivation takes place mainly on abandoned grazing lands. Brazil's president stressed that the increase in oil price has raised the cost of food transport as well as for fertilizers, that the world financial and real estate crisis has led speculators to place their assets in the promising agricultural market. He went even further and condemned the rich countries' protectionist policies, in the form of subsidies (that protect their farmers) and tariffs (that hamper the competitivity of products exported by developing countries). For instance, the European Union imposes a 60% tariff on ethanol and Brazil, which supplies 30% of the ethanol consumed by the Europeans, considers this tariff as absurd and is negotiating on this issue with the European Union since October 2007. Brazil is deeply interested in the European market of agrofuels – ethanol and biodiesel – that may represent about 20 billion liters per year by 2020. President Lula da Silva considers that Brazil has "the land, water, knowledge, technology and 30 years of experience" and is therefore "an unbeatable competitor" that can legitimately win a large portion of the European agrofuel market. Finally, without naming him, President Lula da Silva replied to Jean Ziegler, the former special rapporteur of the United Nations Council of Human Rights on the right to food, that "the true crime against humankind would be to discredit *a priori* biofuels and to condemn the countries that lack food and energy to remain dependent and insecure" (Langellier, 2008).

Although sugar-cane cultivation coexists with food crops such as soybeans, groundnuts and common beans, it has its shortcomings (see pp. 68-70), even though bioethanol production has brought wealth to some regions, and created about 1 million jobs and slowed down rural exodus by mid-2008. The fact is that 90% of marketed new cars are flex-fuel cars, using bioethanol or gasoline, but for the first time in April 2008 bioethanol has been more consumed than gasoline. Brazil expects other large countries like China or India follow its energy policies. If this is to happen in a remote future, bioethanol could become a commodity listed on the stock exchange on the global market, where Brazil wishes to be the unchallenged leader (Langellier, 2008).

Soybeans

Nowadays, soybeans are a very important crop and commodity for the farm economy of the United States, valued at about US$15 billion annually (2006). Soybeans are planted on more than 73 million acres, with a total production of 2.8 billion bushels and an average yield of about 40 bushels per acre.

Soy oil accounts for about 35% of the value of soybeans and over 80% of the total fats and edible oil consumption in the United States. A breakdown of soybean oil uses include baking and frying oils (46 %), salad or cooking oil (43%), margarines (7%), other edible products (1%) and industrial products (3%). Industrial oil uses are rapidly expanding with greater production of biodiesel, and use of polymers and industrial chemicals developed from soybean oil.

Soybean has probably emerged as a domesticate during the Zhou dynasty in the eastern half of northern China. The oldest records appear in bonze inscriptions and in early writings that date not much earlier than the 11th century. Since domestication is a process of trial and error and is not a time-table event, this process probably took place during the Shang dynasty (ca. 1500-1100 BC). By the first century A.D. soybeans were probably distributed throughout China by trade missions and with time to other Asian countries. The earliest Japanese reference to the soybean (Glycine max) was found in the Kojiki (Records of Ancient Matters) that was completed in 712 A.D.

In the 16th and 17th centuries, several references have been made to native soy foods in diaries of European visitors to China and Japan. They reported that the Asians were quite reactive in converting the soybean into several staple foodstuffs such as tofu, soy milk, miso and soy sauce. These foodstuffs were unfamiliar to these early explorers and merchants.

In 1765, the first soybeans were brought to the United States by Samuel Bowen, a seaman employed by the East Indian Company, and planted by Henry Yonge on his plantation "Greenwich" located at Thunderbolt a few miles east of Savannah, Georgia. S. Bowen used the soybean to produce soy sauce and a soybean noodle for export to England. He also exported several agricultural products to England that ended or were drastically reduced by the Revolutionary war in 1776.

In 1770, Benjamin Franklin sent seeds from London to the botanist John Bartram for planting near Philadelphia, Pennsylvania. He also described in a letter to J. Bartram how a cheese (tofu) was made from the soybeans in China. In 1829, Professor Thomas Nuttall grew soybeans in the Botanic Gardens in Cambridge, Massachusetts.

In 1851, Dr Benjamin Franklin Edwards received a gift of Japan peas (soybeans) for professional services he provided to a group of Japanese sailors. Dr Edwards provided the soybeans to a friend, John H. Lea, for planting in his garden in Alton, Illinois. Lea distributed seeds, some were planted by J.J. Jackson in Davenport, Iowa and by A.H. Ernst in Cincinnati, Ohio, the following year.

In 1854, Commodore Matthew Perry's expedition that opened Japan to western trade recorded the use of a bean called the Japan pea (soybean) and obtained seeds for US farmers. The Perry expedition (1852-1854) provided ample publicity to soybeans.

In 1878, George Cook and James Nielson of the New Jersey Agricultural Experiment Station obtained soybean seeds while on a trip to Europe that they planted on the College Farm in 1879. The results of these successful tests were repeated at other agricultural experiment stations.

In the 1890s, soybeans were widely tested as pastures, hay, silage and green cover crops. Feeding studies with horses, cattle, sheep, dairy cows and poultry were conducted at several state university research facilities. Plant parts were analyzed to assess the value of the potential crop.

In 1893, W.P. Brooks at the Massachusetts Station conducted classic studies showing the benefits of inoculation of soybeans at planting and the relationship of nodules to seed yields. Researchers at the New Jersey and Kansas stations confirmed his results.

In 1904, George Washington Carver at Tuskegee Institute discovered soybeans were a rich source of protein and oil. He also encouraged farmers to rotate their crops with soybeans. In 1905, a commercial soybean inoculum (Rhizobium) was marketed. This advance was an important step in assuring successful soybean rooting, growth and development.

In 1911, soybeans from Manchuria were first processed in the United States in a plant near Seattle, Washington State. Domestically produced soybeans were first processed in a cottonseed oil mill owned by Elizabeth City Oil and Ferlilizer Co. at Elizabeth North Carolina.

In 1917, T.B. Osborne and L.B. Mendel demonstrated that heating improved the nutritional quality of soybeans, by inactivating some of heat-labile antinutritional components in soybeans.

In 1920, William Morse founded the American Soybean Association. In the 1920s, John Arvey Kellogg developed meat substitutes and soy milk for American consumers.

In 1929-1931, P.H. Dorsett and William Morse, two US Department of Agriculture's researchers, collected nearly 4,500 soybean accessions from Northeast China, Japan and Korea.

In 1930, soybeans were grown on 3.5 million acres of US land. A University of Illinois bulletin indicated that 56% of the crops was used for hay, 14% grazed and 30% harvested for seed; 42% of the soybean crop was crushed for oil and meal, 34% saved for seed, 23% fed whole to livestock and 2% used for human food.

In the 1930s, Henry Ford was an early promoter of soybeans. The Ford laboratory produced several prototype plastics, new food items and even cloth material from soybeans. In the 1930s, a lot of research on the industrial uses of soybeans was initiated to find users for soybean protein and oil that had not found wide food and feed uses. Soy products found use in paints and coatings, inks, soaps, adhesives, fertilizers and other industrial applications.

1940s : prior to the 1940s, poultry rations were formulated with meat scrape, fish meal, milk products and yeast supplying the protein source. During the 1940s, nutritionists were successful in determining the vitamin, mineral and amino-acid needs of poultry and swine. Soybean-meal use grew as nutritionists gained an understanding of formulating diets to meet animals'/birds' nutrient requirements.

In the late 1940s, oil chemists conducted a lot of research to improve the soy oil's flavour stability problem. They found that oxidative flavour and odour changes occurring during refining could be prevented. The improved oil quality allowed soybean oil to be competitive with other quality vegetable oils.

In 1947, several research groups demonstrated that the "animal growth factor" supplied by animal by-products were vitamin B12. This allowed the swine and poultry nutritionits to develop high performance diets based on maize and soybean meal.

1960s: soybean meal's balanced nutrient composition, reasonable cost and availability to the feed manufacturer have fostered the rapid growth of the livestock and poultry production. Nowadays, efficient livestock and poultry production relies on cereal grain and soybean meal rations. The feed demand for soy protein drives the growth of soybeans worldwide.

1990s : one of the most significant advances of agricultural biotechnology was the wide acceptance of herbicide tolerant varieties that would reduce the cost and labour involved in controlling weeds in soybeans, in addition to no tillage farming.

2000s: soybeans are finding increased use in biodiesel fuels, biodegradable polymers, environment friendly lubricants and many other industrial chemicals.

2008 : deciphering of the soybean genome.

Soybean meal has become the protein of choice for feed manufacturers. The United Soybean Board estimated that 46% of the soybean produced in the United States was used for broilers, layers and turkeys. Swine used another 25%, with beef (13%), dairy (8.5%), pet foods (2.5%), other feed (2%) and food and industrial uses (2.5%), respectively in 2006 (*Soybean Meal Information Center Fact Sheet, Soybeans - History and Future*, 4 p.).

Impact of bioethanol production on grain output

The US Department of Agriculture (USDA) projected that distilleries would require only 60 million tons of maize from the 2008 harvest (312 million tons). But the Earth Policy Institute (EPI) – Lester R. Brown – estimated that distilleries would need 139 million tons, more than twice as much. Consequently, the competition between agrofuel consumption and grain for food would likely drive world grain prices to high levels. The USDA heavily relies on the Renewable Fuels Association (RFA), a trade group, for data or ethanol distilleries under construction. The other three firms providing the relevant data are Europe-based F.O. Licht, the publisher of *World Ethanol and Biofuels Report*; BBI International, which publishes *Ethanol Producer Magazine*; and the American Coalition for Ethanol (ACE), publisher of *Ethanol Today* (Brown, 2007).

According to the EPI compilation, the 116 plants in production on 31 December 2006 were using 53 million tons of grain per year, while the 75 plants under construction – mostly larger facilities – will use 51 million tons of grain when they come on line. Expansions of existing plants will use another 8 million tons of grain (1 ton of maize = 39.4 bushels = 110 gallons of ethanol) [Brown, 2007].

In addition, 200 ethanol plants were in the planning stage by the end of 2006. If construction were carried out between January 1st and June 30th, 2007, at the same rate that plants ded during the final six months of 2006, then an additional 3 billion gallons of capacity requiring 27 million more tons of grain will likely come online by 1st September 2008, the start of the 2008 maize harvest. This raises the maize needed for distilleries to 139 million tons. This would yield nearly 15 billion gallons of bioethanol, meeting 6% of US auto fuel needs.

The US maize crop, accounting for 40% of the global harvest and supplying 70% of the world's maize exports, looms large in the world food economy. Annual US maize exports of some 55 million tons account for nearly one fourth of world grain exports. The maize harvest of Iowa alone, which edges out Illinois as the leading producer, exceeds the entire grain harvest of Canada. Substantially reducing this export flow would have a significant impact on the world economy (Brown, 2007).

Fuel ethanol proponents point out, and rightly so, that the use of maize to produce ethanol is not a total loss to the food economy, because 30% of the maize is recovered in distillers dried grains that can be fed to beef and dairy cattle, pigs, and chickens, though only in limited amounts. They also argue that the US distillery demand for maize can be met by expanding land under maize, mostly at the expense of soybeans, and by raising yields. While it is true that the maize crop can be expanded, there is no precedent for growth on the scale needed. And this soaring demand for maize comes when world grain production has fallen below consumption in six of the last seven years, dropping grain stocks to their lowest level in 34 years (Brown, 2007).

There are alternatives to creating a crop-based automotive fuel economy. The equivalent of the 2% of US automotive fuel supplies now coming from bioethanol could be achieved several times over, and at a fraction of the cost, by raising autofuel efficiency standards by 20% (according to the EPI). If we shift to gas-electric hybrid plug-in cars over the next decade, we could be doing short-distance driving, such as the daily commute or grocery shopping, with electricity. If we then invested in thousands of wind farms to feed cheap electricity into the grid, US cars could run primarily on wind energy– and at the gasoline equivalent of less than US$1 a gallon (Brown, 2007).

The policy goal should be therefore to use just enough fuel ethanol to support maize prices and farm incomes but not so much that it disrupts the world food economy. Meanwhile, a much greater effort is needed to produce bioethanol from cellulosic sources such as switch grass, a feedstock that is not used for food. As the leading grain producer, grain exporter and bioethanol producer, the United States need to make sure that in trying to decrease its dependence on imported oil, it does not create serious disturbance in the world food economy (Brown, 207). See also Hazell and Pachauri (2006).

However, if it is true that the main function of agriculture is to feed the world, one should not oppose food and non-food needs, as stated by the president of the French sugar cooperative Tereos – an important actor in bioethanol production in both France and Brazil. He emphasized that tens of millions hectares are still available for cultivation in Russia, Ukraine, Brazil or Mozambique and that yields could be increased on already cultivated lands. But this requires transportation means, ports, in other words investments and rewarding prices. Philippe Duval, president of Tereos, underlined that the real issue was that over the last 50 years commodity prices have been falling and there was no incentive for farming new lands worldwide. Consequently, he states that the increasing food needs of humankind could be met only when funding and investment priority are given to agriculture in both industrialized and developing countries. And within the framework of a more productive agriculture, whose sustainability is supported by prioritary funding and research, it seems legitimate to set reasonable targets for biofuel production (Clavreul, 2008). The alleged impact of biofuels on food price is therefore disproportionate and a number of factors, including poor harvests in Australia and Ukraine in 2007, and an increased demand for meat in some developing countries, have a much more significant impact. See also Energy Transition - Creative Energy (2008).

Although it has been often stated that increased maize use for biofuels in the United States would cause food shortages in Africa and elsewhere because of reduced stocks and exports, the facts show that US maize exports, though less in 2006-2007 than in 2005-2006, were still above the average of the past ten years: they reached 2.45 billion bushels. It is also important to highlight that most of the maize exported by the United States is used for cattle feed, not for human food in developing countries. It was expected that for 2008 the production of biofuels would require about 60 million tons of cereals versus a worldwide cereal production well in excess of 2 billion tons. The increase in maize production of about 65 million tons in the United States alone in 2006-2007 would be sufficient to meet that need (*EuropaBio Biofuels Factsheet*, April 2008).

Increase in food prices

Peaks in food prices registered in 2007 and 2008, particularly those of wheat and maize, are not unprecedented. In the past 30 years, maize price went above €120 per ton in 1981, 1983 and 1995 for reasons totally unrelated to bioethanol production, which was virtually non-existent before 2001, and fell back after one or two years (*EuropaBio Biofuels Factsheet*, April 2008).

Globally, world meat production has increased by about 65% during the last 20 years, increasing the demand for feed. For the production of 1 kg of meat on average at least 3 kg of cereals are needed. Meat consumption in China alone increased from 27 kg to 59 kg per person per year between 1990 and 2005. Each additional kilogram increase on average in China results in a need of roughly 3 million tons of animal feed. Meat production in China reached around 81.18 million tons in 2006, compared with 30.32 million tons in 1990. This increase in meat consumption in China, India and other developing countries whose standard of living is improving has been an important driver of the rising price of cereals on the world market (EuropaBio Biofuels Factsheet, April 2008). This issue is not without polemics. For instance, the Indian political class has been infuriated by the comments made by the US president George W. Bush on the responsibility of Indian middle class, increasingly better off, for the higher consumption of foodstuffs (particularly meat and milk products) and consequently for higher food prices (Kauffmann, 2008).

The price tension on the market created by high demand was reinforced by poor harvests and record oil prices. According to the Food and Agriculture Organization of the United Nations (FAO), much of the poor performance of world agriculture in 2006 was due to disappointing cereal production, which fell for the second consecutive year as a result of poor weather conditions. The cereal harvest was especially poor in Australia and the United States where it fell by 60% and 7% respectively. Production was also down in the European Union, Canada, Argentina and South Africa (*EuropaBio Biofuels Factsheet*, April 2008).

Additionally, between 2003 and early 2008, the price of oil has increased from US$25 to US$100 per barrel, heavily impacting agriculture production, processing and transportation costs (*EuropaBio Biofuels Factsheet*, April 2008).

On 18 January 2008, in Berlin, the European Union Commissioner for Agriculture and Fisheries, Ms Fischer Boel stressed that the increase in food prices is not solely due to the rise of agricultural raw materials; cereals, for instance, only make up around 4% of the consumer price of bread (*EuropaBio Biofuels Factsheet*, April 2008).

Analysts consider that the 2006-2008 increase in food prices must be put in perspective. Historically, food prices are low compared with food prices over the last century. The National Farmers' Union estimated that if the price of wheat had increased with inflation, it would now be worth about €900 per ton rather than €150 per ton by April 2008. Food prices have decreased over the last 30 years (60% from base level 100 in 1957) and the cost of raw material has fallen about 20% from base level 100 in 1957. Secondly, food prices and agricultural raw material prices are not directly linked in developed countries. Energy prices have a two to three times higher impact on retail food prices than raw materials prices. Following the oil crisis in 1973, the price of food soared by 200%.

Finally, in developed countries, the share of raw material costs in final products is rather limited: only 10% for bread and 20% for chicken in the United States. The bulk of the costs are associated with processing and distribution. However, in developing countries, the price of food is more directly linked to raw material prices (EuropaBio Biofuels Factsheet, April 2008). See also Energy Transition - Creative Energy (2008).

According to the US Department of Agriculture's calculations, maize prices were expected to increase by 3%-6% per billion gallon increase in the demand for maize-derived ethanol in the United States. The impact on wheat prices per billion gallon increase in the demand for bioethanol could range from 0.6% to 2.1% rise. A 14% share of biofuels in the European Union's transportation sector would imply an increase in price of 6% for wheat and 13% for rapeseed oil, but would cause the prices of rapeseed meal and soybean meal to fall by approximately 40%. Overall, the studies in the European Union and United States indicated that price rises for agricultural commodities for industry would be limited relative to the prices in force in 2008 (*EuropaBio Biofuels Factsheet*, April 2008).

It seems, therefore, that the amount of the contribution of agrofuel production to higher food prices (and even shortages) is disputed. Work by the International Food Policy Research Institute (IFPRI, Washington, D.C.) suggested that agrofuel production accounted for a quarter to a third of the increase in global commodity prices. The Food and Agriculture Organization of the United Nations (FAO) predicted by late 2007 that agrofuel production, assuming that current mandates continue, would increase food costs by 10% to 15%. Ron Litterer, president of the National Growers Association of the United States, stated that "there is no question that they (agrofuels) are a factor but they are really a small factor than other things that are driving up prices" (Martin, 2008).

According to the World Bank, global food prices have increased by 83% in the last three years. Rice, a staple food for nearly half of the world's population, has been a particular focus of concern, with spiralling prices prompting several countries to impose drastic limits on exports as they tried to protect domestic consumers (Martin, 2008). The Asian Development Bank (ADB), which made the commitment to allocate US$2.5 billion to help agriculture between mid-2008 and the end of 2009, has estimated that about 1 billion people in Asia were seriously hurt by the increase in food prices. It is true that the fast increase in the standard of living in Asia has spurred food demand, but still more than 600 million people live with less than one dollar per day (Kauffmann, 2008).

The price of rice, that supplies one third of the caloric needs of Asians, started to increase in 2005; at the beginning of 2006, it was worth more than US$300 per ton, and in April 2007 it reached almost US$1,000 per ton. But this was not the result of the transformation of rice into agrofuels! That was the conclusion of Milan Brahmbhatt, economist at the World Bank and specialist of the Asia-Pacific region. It is indeed difficult to replace paddy fields and rice by fuel producing crops. An exception is Myanmar (Burma) whose military regime decided to grow jatropha in some areas, without taking account of the nature of soils and the farmers' capacity to transform jatropha oil into biodiesel. One should recall that before the installation of the military regime and the launching of the "Burmese way to socialism", in 1962, Burma had been the first rice-exporting country. Since then rural poverty has been spreading over the country and food self-sufficiency was lost. In 2008, the hurricane Narjis submerged the Irrawady rice-growing region and granary of the country, and destroyed 80% of crops, according to FAO. This agricultural and human disaster had a negative impact on the availability of rice in Asia and on its prices (Kauffmann, 2008). See also Pons (2008).

About a fifth of the United States maize crop is now used to produce bioethanol for motor fuel, and as farmers have planted more maize, they have cut acreage of other corps, particularly soybeans. That may have contributed of a global shortfall of cooking oil. C. Ford Runge, an economist at the University of Minnesota, stated it was "extremely difficult to disentangle" the effect of agrofuels on food costs. Nevertheless, he said there was little that could be done to mitigate the effect of droughts and the growing demand for protein in some developing countries. "Ethanol is the one thing we can do something about", he stated. But August Schumacher, a former US undersecretary of agriculture, who is a consultant for the Kellogg Foundation, stated the criticism of agrofuels might be misdirected. He noted that many of the upheavals over food prices abroad have concerned rice and wheat, neither of which is used as a biofuel. For both crops, global demand has soared at the same time that droughts (in Australia, Ukraine, etc.) suppressed the output from farms (Martin, 2008).

While the aid non-governmental organization Oxfam underlined that agrofuels were a major cause of the increase in global food prices, it called on rich countries to dismantle subsidies for agrofuels and reduce tariffs on imports. Oxfam's June report stated: "Rich countries, spent up to US$15 billion in 2007 supporting agrofuels, while blocking Brazil's cheaper bioethanol, which is far less damaging for global security" (Harrison, 2008).

This statement recognized the difference between maize mainly grown in the United States and its transformation into bioethanol, and cane sugar, the feedstock used by Brazil for producing bioethanol. In a way, it strengthens the position of Brazil who has consistently defended its agrofuel policy and denied it was responsible for food scarcity or shortage (see pp.68, 69).

With regard to the elimination of subsidies for agrofuels, this might happen when the barrel of oil has reached a threshold, e.g. US$80 according to some analysts. According to Alain Anselme, chairman of the French Trade-Union of Agricultural Alcohol Producers (SNPAA), "oil price will continue to increase as it is a non-renewable resource, while the cost of plant resources does not increase to the same extent, because of the potential productivity and the possibility to substitute plant species with others, such as maize, wheat, barley, rye, beet, and even biomass". Other analysts, like Rodolphe Roche of the managing company Schroders in London, consider that one should look at the issue beyond the price. He underlined that "Americans whatever their political slant, want to acquire an energy independence". In addition, through bioethanol the United States can subsidize their agriculture, when the negotiations at the World Trade Organization would lead to a drop of subsidies to US farmers. Finally agrofuel production and consumption give the United States a better image with respect to environmental protection, as they have not ratified the Kyoto Protocol on the drastic reduction of the emissions of greenhouse-effect gases (Faujas, 2007).

Agrofuels, indeed, are fast becoming a new source of debate in global diplomacy, putting pressure on developed countries to reconsider their policies, even as they argue that agrofuels are only one factor in the rise in food prices. A number of food policy specialists consider government mandates for agrofuels to be ill advised, agreeing that the diversion of crops like maize into fuel production has contributed to the higher prices. But other factors have played big roles, including droughts that have limited output, particularly in grain-exporting countries, and rapid global economic growth that has created higher demand for food. Such a growth, much faster since 2003 than the historical norm, is lifting millions of people out of poverty and giving them access to better diets. But farmers could not keep up with the surge in demand (Martin, 2008). See also Energy Transition - Creative Energy (2008).

One may ask whether the use of agrofuels and its advantages for the environment protection can justify the cost for part of humankind that cannot pay for its staple food. Milan Brahmbhatt, economist at the World Bank, wondered: "what is the value of future human well-being (which aims at protecting the environment) versus the value of current well-being (achieved thanks to affordable food prices)"? This is one of the key issues of the debate on climate change. The report by Nicholas Stern on the economy of climate change, published at the end of 2006, privileges future human well-being. In April 2008, another report by the International Association of Agricultural Science and Development Technology warned that "modern agriculture should change drastically if the international community wanted to cope with both growing populations and climate change". In fact, development agencies like the World Bank, and governments did little to support agricultural development and change (produce more and better) during the last two decades (Kauffmann, 2008).

Is it realistic to reconsider agrofuel production targets?

Despite the fact that available data and detailed reviews do not lead to the conclusion that agrofuel production worldwide is the most important cause of the increase in food prices, Oxfam urged countries to scrap agrofuel targets, including European Union's plans to derive 10% of transport fuels from renewable sources by 2020. The NGO estimated that by 2020, CO_2 emissions from changes in land use in the palm-oil sector might reach more than 3.1 billion tons, largely as a result of the European Union target, and, that it would take more than 46 years of agrofuel use at 2020 levels to repay this "carbon debt" (Harrison, 2008).

Is it realistic? For instance, France has launched an ambitious plan in 2005 to build some 20 agrofuel plants with important subsidies. In 2008, the new French government was lukewarm about carrying out such a plan; but the director of Sofiprotéol, which is the financial arm of the cultivation and processing of sunflower and oilseed-rape in France, and had invested more than €500 million over two years in the agrofuel business, while owning seven biodiesel plants, stated that "they needed more visibility and that their strategy was to optimize their production tool, emphasizing sustainability" (Clavreul, 2008).

With respect to bioethanol, €1 billion had been invested by various actors. Tereos, a cooperative that owned five plants and aimed at pursuing its development in Brazil, expected the French government not to change the rules of the game, especially with regard to tax exemption (Clavreul, 2008).

On 22 April 2008, in Rome, at the International Energy Forum, the French minister of ecology and energy development made a plea in favour of a "pause on building new capacities" for the first-generation fuels derived from grains and oilseed-rape. At the same time, he stated that the investments already launched will be "honoured", and the minister emphasized the need to focus on second-generation fuels that will use non-food crops and cellulosic wastes (Clavreul and Bezat, 2008).

The French minister of agriculture replied to his colleague the day after (23 April 2008) on a French radio channel: "The issue is no that of agrofuels", but "the place they occupy". He underlined that France in 2010 will devote only 7% to 12% of its arable lands to the production of agrofuels, far behind the United States and Brazil (20%-30%). Whatever the position of each minister, the objective is the same, i.e. to mix 7% of agrofuel in motor-car fuel by 2010. The president of the French Republic did confirm this objective at the beginning of April 2008 at the congress of the main federation of agricultural trade-unions. That was not the case of the Confédération paysanne – the other association of farmers – which was not initially opposed to agrofuels, but then voiced its concerns about their impact on the price of food and feed in the world and also in France; livestock husbandry was particularly hurt by the increase in feed prices. On the other hand, the farmers who signed contracts to supply bioethanol plants, were losing money according to the trade-union, particularly those who were delivering grains to Tereos' plant at Lillebonne (Seine-Maritime) and who committed themselves for five to ten years to supply wheat at a price twice less expensive than that of 2008 (Clavreul, 2008; Clavreul and Bezat, 2008).

Bioethanol producers replied that "without agrofuels, France will not be able to meet its commitments in terms of renewable sources of energy" (20% in 2020). In fact, they should not be worried, because the 20 agrofuel plants foreseen to meet the 2010 target were already in service or under construction. The French Union of Oil Industries (UFIP) considered that it would be difficult to reach the objective of 5.75% of agrofuel in the transportation fuels in 2008, and it demanded to come back to the European norm, less ambitious and gradually reaching 10% by 2020. In its report *Perspectives énergétiques de la France à l'horizon 2020-2050* (Energy prospects of France at the horizon 2020-2050), delivered to the French prime minister in September 2007, Jean Syrota supported the end of tax exemption for bioethanol and "the halt of new investments in the production of first-generation biofuels" (Clavreul and Bezat, 2008).

While France was chairing the European Council from July to December 2008, a decision should be made regarding the target of 10% of agrofuel in transportation fuels by 2020. The United Kingdom and Belgium seemed to be willing to review the issue if it were demonstrated that agrofuels had a direct impact on the steep rise in commodity prices. Germany stated on 23 April 2008 that it kept the European objective, but reduced what was set up for 2010 for bioethanol production (Clavreul and Bezat, 2008).

Would it be possible for France to move, after 2010, towards the second-generation agrofuels, if the full development of the first-generation ones were hindered? Research is being carried out on the second-generation biofuels in several countries, but there are still few industrial plants. In Europe, the first plant was inaugurated in Germany by Chancellor Angela Merkel by April 2008, but another ten years will be necessary before achieving commercial production of this kind of agrofuels (Clavreul and Bezat, 2008).

Royal Nedalco, which has been making alcohol at Bergen op Zoom, Netherlands, since 1989, mostly for liquor and industrial use, wanted to make ethanol for fuel out of cellulose, using a yeast found in elephant dung. Mascoma Corp., a Massachusetts-based biotechnology firm, is partnering with the Dutch company in moving this project ahead, as well as agribusiness giant Cargill Inc. (Brasher, 2007a).

The International Institute for Sustainable Development, based in Switzerland, estimated at least US$36 million had been spent on research and development on agrofuels (including on “cellulosic” ethanol) in 2006. The European Commission was spending US$14 million a year on biofuel research with plans to increase that amount by 50% (Brasher, 2007a).

Even so, we should not expect that the second-generation agrofuels will upheave the role of biofuels among the various solutions aiming at the partial substitution of fossil fuels. Thomas Guillé of the French International Cooperation Centre on Agricultural Research for Development (CIRAD) has calculated that of the 4 billion tons of agricultural wastes annually produced in the world, and taking into account their different uses, only 300 million tons could be transformed into agrofuels. This figure, even though wood production was omitted, should be compared with the world production of primary energy that presently amounts to 11 billion tons of oil-equivalent (Caramel, 2008a).

Agrofuels and deforestation in tropical regions

Deforestation on a large scale has been occurring for at least a century and has its own dynamics linked with the trade of tropical wood and the wide use of these woods in construction and furniture. Deforestation is often the result of poorly regulated trade of tropical wood and a lack of political will to enforce forest policy. Agrofuels, by introducing a new demand, can indeed put pressure on forest resources. Establishing and enforcing sustainability criteria for agrofuels are crucial to ensure that their production does not worsen deforestation (*EuropaBio Biofuels Factsheet*, April 2008).

The use of vegetable oils for biofuels was estimated at about 5 million tons in April 2007. From 2003 to 2006, the production of vegetable oils has increased by 18.3 million tons, with increases of 4.9 million tons for oilseed rape, 4.7 million tons for soybeans and 8.7 million tons for palm oil. Hence the use of vegetable oils for biodiesel production cannot be the only cause for the recent increase in vegetable oil production (*EuropaBio Biofuels Factsheet*, April 2008).

Environmentalists want to make sure that sugar-cane cultivation for bioethanol production in Brazil does not encroach on the Amazonian ecosystems. The protection of the latter is the source of polemics, despite the efforts made by the government to control illegal logging and the expansion of cattle rearing. On 13 May 2008, Marina Silva, the minister for environment, resigned from her post because of divergent views on the development of Amazonia, when five days earlier the Plan for a durable Amazonia was launched. On 20 May 2008, President Lula da Silva appointed Carlos Minc, as the new minister for environment. He was a co-founder of the Brazilian Green Party and was awarded the United Nations Global 500 Prize for its activities aimed at protecting the environment. He became member of the Workers Party (PT) – the party of President Lula da Silva – by the late 1980s. As environment secretary of the State of Rio de Janeiro, Carlos Minc has been trying to link the industry more closely with the environmentalists and to obtain more resources, including from the international community. He also wanted to issue tax incentives in order to enhance environment protection. Acknowledging the increase in the deforestation rate in 2007, he stated during a press conference in Paris in May 2008 that “under his managerial leadership, not a single tree will be felled for the production of agrofuels” (Krieger, 2008). See also Hazell and Pachauri (2006).

Environmental and social impact of oil-palm expansion for biodiesel production

Spurred by government subsidies in the Netherlands, energy companies designed generators that ran exclusively on palm oil imported from South-East Asia. Rising demand for palm oil in Europe brought about the razing of huge tracts of South-East Asian rain forest and the overuse of chemical fertilizer there. Worse still, space for the expanding oil-palm plantations was often created by draining and burning peat land, which sent huge amount of carbon emissions into the atmosphere (Rosenthal, 2007).

Indonesia quickly became the world's third-leading producer of greenhouse-effect gases, behind the United States and China, concluded a study released in December 2007 by researchers from Wetlands International and Delft Hydraulics, both in the Netherlands. In this country, these data have provoked soul searching, and prompted the government to suspend palm-oil subsidies. A country that was a leader in green energy in Europe has now become a leader in the effort to distinguish which agrofuels are truly environmentally sound. The government, environmental groups and some of the "green energy" companies in the Netherlands are trying to develop programmes to trace the origin of imported palm oil, to certify what is produced in an ecofriendly manner (Rosenthal, 2007).

This may lead politicians in several countries to rethink the subsidies that have supported the spread of agrofuels for use in power vehicles and factories. Biofuels Watch, an environmental group in the United Kingdom, supported a moratorium on subsidies until more research helps to define which biofuels are truly good for the planet. Beyond that, the group suggested that all emissions arising from the production of an agrofuel be counted as emissions in the country where the fuel was actually used, providing a clearer accounting of environmental costs (Rosenthal, 2007).

Concerning palm oil, its demand in Europe has skyrocketed in the past two decades, first for use in food and cosmetics, and more recently for agrofuels. This versatile and low-cost oil is used in about 10% of supermarket products, from chocolate to tooth paste, accounting for 21% of the global market for edible oils. Palm oil produces the most energy of all vegetable oils per liter when burnt. In much of Europe it is used as a substitute for diesel oil, though in the Netherlands, with little sun for solar power, the government has encouraged its use for electricity (Rosenthal, 2007).

Supported by hundreds of millions of euros in national subsidies, the Netherlands rapidly became the leading importer of palm oil in Europe, taking in 1.5 million tons in 2006, a figure that has been nearly doubling annually. The Dutch green energy giant Essent alone bought 200,000 tons, before it agreed to suspend new purchases until a better system for certifying sustainably grown oil-palm could be developed. The company has replaced the palm oil it used with conventional sources of energy and local agrofuels (Rosenthal, 2007).

Friends of the Earth estimated that 87% of the deforestation in Malaysia from 1985 to 2000 was caused by new oil-palm plantations. In Indonesia, the amount of land devoted to oil-palm has increased 118% during the eight-year period 1999-2006. Oil needed by poor people for food was becoming too expensive for them (Rosenthal, 2007).

Such concerns were causing intense misgivings about palm oil already when, in December 2006, scientists from Wetlands International released their bomb shell calculation about the global emissions that palm farming on peat land caused. (see p.124). The Dutch study estimated that the draining of peat land in Indonesia released 600 million tons of carbon into the atmosphere a year and that fires contributed an additional 1,400 million tons annually. The total, 2 billion tons, is equivalent to 8% of all global emissions caused annually by burning fossil fuels, according to Wetlands International researchers (Rosenthal, 2007).

Some environmental groups are convinced that palm oil cannot be produced sustainably at reasonable prices. Part of the reason palm oil is now relatively inexpensive is because of poor environmental practices and labour abuses, according to Wetlands International. But some Dutch companies like Biox, a young company devoted to producing energy from palm oil, are confident there will be a solution and are banking on this agrofuel. Biox has applied to build three palm-oil power plants in the Netherlands; the first one gained approval by early 2007. It is auditing its plantations and refineries in Indonesia for sustainability. In other words, to serve Europe's markets for agrofuel and bioenergy, one has to prove that this energy is produced in a sustainable way, that one produces less, not more CO_2 (Rosenthal, 2007).

Example of Riau (Indonesia)

As an example of the intense pressure on forested land in South-East Asia with a view to expanding oil-palm plantations for agrofuel production, the case of the province of Riau is worth mentioning. This province with an area equivalent to that of Portugal contains a remaining part of the primary rainforest that used to cover most of the 443,000 km2 of the island of Sumatra. During the 1990s, the villages settled along the Indragiri river had been struggling against the state-owned company Inhutani, which was felling trees without any restraint. In 2004, another company, Duta Palma, had been authorized to create oil-palm plantations. In Sumatra, there are no land-property certificates, but just traditional permits, which can be superseded by authorizations given by the regional government. Duta Palma's subsidiary companies, BBU and BAY, destroyed the forest, where villagers used to collect and gather their traditional products. In January 2007, villagers were able to obtain a letter from the district's head, headquartered at Pekanbaru, Riau's capital, ordering the companies not to invade the villagers' lands (Kempf, 2008).

This struggle drew the attention of several Indonesian environmentalist associations, then of Greenpeace, which decided to set up an observation site for a few weeks. But in December 2007, Greenpeace left Riau. The problems remained unsolved while there were ways and means to grow oil-palm without harming the traditional life of villagers, particularly their access to the primary forest resources. The director of PT Smart, a company that owns 350,000 hectares of oil-palm plantations in Sumatra, stated that "it was necessary to develop our country, but we can do it without destruction". PT Smart has joined other companies in participating in a roundtable on oil-palm, which decided in November 2007 not to develop crops at the expense of primary forests, but only on already exploited forest or on degraded land (Kempf, 2008).

Agrofuels and climate change

Paul Crutzen of the Max-Planck-Institut für Chemie, Mainz, Germany, the 1995 Nobel laureate in chemistry for his work on the degradation of the stratospheric ozone layer, has co-signed a publication by an international team of researchers in *Atmospheric Chemistry and Physics Discussions* that concluded that the production of one liter of agrofuel could contribute to the greenhouse effect twofold more than the same volume of fossil fuel. Paul Crutzen and his co-authors dealt with the emissions of nitrogen protoxide (N_2O) due to intensive agriculture. This gas contributes 296 times more to the greenhouse effect than carbon dioxide (CO_2), on equal volumes (Foucart, 2007).

Part of nitrogen fertilizers used to increase crop yields is degraded in soils into N_2O. The Intergovernmental Expert Group on Climate Change has estimated at 1% the rate of conversion of fertilizers nitrogen into N_2O.

To evaluate this rate, the experts have measured the emissions of the plants themselves, while P. Crutzen and co-authors have reviewed the problem globally. They observed the variations of N_2O concentration in the atmosphere and correlated them with the quantities of nitrogen fertilizers added to the environment since the beginning of the industrial era. After having taken account of emissions due to other activities, they concluded that the rate of conversion of agricultural nitrogen into N_2O was three to five times higher than previous estimations, i.e. between 3% and 5%. It should be underlined that the margin of error is important in this kind of calculations, because the measurement of N_2O in the atmosphere is not as accurate as it should be, due to the lack of a network of monitoring centres (Foucart, 2007).

Based on this conversion rate, the combustion of biodiesel produced from oilseed rape (80% of biodiesel in Europe is produced from rapeseed oil) contributes to the global rise of temperature 1 to 1.7 times more than the use of the same quantity of fossil fuel. This ratio is estimated at between 1.3 and 2.1 for bioethanol produced from wheat, and at between 0.9 and 1.5 for bioethanol from maize. David Reay of Edinburgh University has calculated, on the basis of P. Crutzen's evaluations, that the sevenfold increase by 2022 of the US production of ethanol from maize, as supported by the US Senate, would lead to a 6% increase in emissions associated with transportation. Only sugar-cane cultivation does not have a negative impact on climate change, the conversion rate amounting to between 0.5 and 0.9 (Foucart, 2007).

Do agrofuels increase the incomes of the rural poor in developing countries?

In the past, agricultural price rises in OECD countries have been sharply lower than inflation. Therefore producers in developed countries could only survive by virtue of market distorting subsidies and the creation of import barriers for competing products from developing countries. Christopher Flavin, president of the Worldwatch Institute stated: "Farmers in some of the poorest nations have been decimated by US and European subsidies to crops such as corn, cotton and sugar. Today's higher prices may allow them to sell their harvests at a decent price, but major agricultural reforms and infrastructure development will be needed to ensure that the increased benefits go to the world's 800 million undernourished people, most of whom live in rural areas". Concern does remain for the urban poor who are not farmers and the rising food prices may have to be regulated by local governments (*EuropaBio Biofuels Factsheet*, April 2008).

Agrofuel production may have caused increased volatility in food prices in the short term but it is also giving price signals to farmers to start producing more. The 2007 United Nations Report *Sustainable Bioenergy, a Framework for Decision Makers* has examined the implications of bioenergy on agro-industrial development and job creation. The report found that "successful bioenergy industries bring significant job creation potential" and "because the vast majority of bioenergy employment occurs in farming, transportation and processing, most of these jobs would be created in rural communities where underemployment is a common problem". The same report quoted the benefits especially of second-generation fuels which will "create higher-value co-products (and thus greater wealth generation)". [*EuropaBio Biofuels Factsheet*, April 2008].

In northern Zambia, diesel cost more than US$2 per liter by April 2008, because of the high transport costs associated with the transport of diesel from the Indian Ocean to remote areas. Growing the right crops could lower the price of diesel and thus spur small-scale solutions and local development projects. In Malaysia, palm-oil prices rose dramatically leaving Malaysian biorefineries without oil for domestic production as they could not afford the current price. That price increase was not primarily due to biodiesel production in Europe or the United States, which represented 5% of palm-oil use, but rather by the change in health policies in the European Union and the United States aiming at lowering or even eliminating trans-fatty acids content in food, thus inducing a substitution of soybean oil for palm oil in foodstuffs (*EuropaBio Biofuels Factsheet*, April 2008).

It is important to provide farmers with tools they can use to serve new markets and increase or diversify their income. Non-food crops for agrofuels can contribute to diversifying farmers' production with cash crops and provide them with an income, even on a very small scale, in a similar way that fiber crops have done in the past. Country-by-country analysis must be carried out to define the best solution and the potential impacts of agrofuels on poverty (e.g. land administration systems, investments, market coordination, impact on labour and transportation costs, relevant technologies). See also Hazell and Pachauri (2006).

CONCLUSIONS : MEETING DEMANDS OF FOOD, FEED AND FUEL

The 2006 European Commission Report on the progress made in the use of biofuels and other renewable fuels in the member states of the European Union showed that – as a result of the assigned targets – the EU would acknowledge a 120,000 increase in net employment and a 0.17% rise in the overall EU's gross domestic product, assuming all agrofuels were produced locally from local feedstocks. Thanks to first and second-generation agrofuels, European farmers would be able to live on their production rather than receiving subsidies in exchange for lower production levels (*EuropaBio Biofuels Factsheet*, April 2008).

Regarding crop yields, maize production in the United States, by far the largest producer and exporter, has increased from 265 million tons (2006) to 327 million tons in 2007 (312 million tons in 2008), thus helping to adjust to the new market demand. In the past 40 years, yields of maize have steadily increased from about 4.5 tons per hectare to 9.4 tons per hectare in the United States, and from 2.3 tons/ha to 4.8 tons/ ha (average) worldwide. By 2015, yield in the United States was expected by the National Corn Growers Association to further increase to 11.2 tons/ha.

In Brazil conventional sugar-cane produces up to 110 tons per hectare which are transformed into approximately 7,500 liters of ethanol (per hectare) plus sugar. A new genetically engineered variety of sugar-cane could produce up to 200 tons per hectare. Coupling the conventional agrofuel production with a second generation (cellulosic) processing technique, the total cane production could be transformed into 22,000 liters of ethanol. According to Fernando Reinach, chief executive of Votorantim Ventures (Votorantim is Brazil's biggest industrial conglomerate), plant science and biotechnology could treble agrofuels production from a hectare of land (*EuropaBio Biofuels Factsheet*, April 2008).

Meeting the European targets for a replacement of liquid fuel for transportation by 10% in 2020 in a sustainable and competitive way, entails the available biomass should be increased. Cultivating energy crops on set-aside and non-cultivated land would help, but it would not be sufficient to fulfill all the demand. It would be also critical to increase land productivity, i.e. more biomass output per hectare, as well as crop quality, e.g. crops that produce more fermentable carbohydrates or contain more oil. This can be achieved through modern plant breeding techniques and biotechnology. Another important step will be the competitive production of agrofuels from (hemi) cellulose and organic agricultural wastes instead of from starch, sugar and oils; these are the second-generation agrofuels, which need important investments in research and development.

Thirdly, innovation in crop breeding and improvement should aim at reducing the amounts of water used in agriculture. In regions where maize or sugar-cane is irrigated, the water withdrawal per liter of agrofuels can be up to 3,500 liters. This withdrawal has a direct impact on immediate water availability for human consumption and food production. In Europe, where rainfed oilseed-rape or cereal is used, the amount of water for agrofuel crop through irrigation is small. In the United States, where mainly rainfed maize is used, only 3% of all irrigation withdrawals are devoted to agrofuel crop production, corresponding to 400 liters of water per liter of bioethanol. The breeding of drought-tolerant crops to minimize water use is therefore a promising area of research. Thus, agricultural and plant biotechnology can help to: increase biomass yield per hectare, while reducing inputs; improve crop quality (higher agrofuel yields); reduce land-use competition through higher productivity and reduced losses from biotic (pests, viruses) and abiotic (drought, salinity) stresses; contribute to the cultivation of energy crops in marginal lands; develop efficient micro-organisms and enzymes to convert hemicelluloses and cellulose into fermentable sugars.

Several studies have been published on the eco-efficiency of agrofuels. They found that CO_2 reduction with the present technologies were between 20% and 80% compared with using conventional gasoline. This can increase to 90% for second-generation agrofuels such as "cellulosic" ethanol or syndiesel. High productivity and energy feedstocks, less fuel-intensive cultivation of crops and low carbon conversion processes could further help in achieving this objective (*EuropaBio Biofuels Factsheet*, April 2008).

To sum up, although a report produced by an independent arm of the Organization for Economic Cooperation and Development (OECD) warned that agrofuel development could cause food shortages and damage to biological diversity while providing limited benefits, we should not ignore the gains made in crop yields and overlook the benefits of reducing oil consumption. In the developing countries, the impact of agrofuel will vary from country to country. John Hoddinot, a senior research fellow at the International Food Policy Research Institute (IFPRI) in Washington, D.C., stated that farmers in Brazil and other countries that produced more food than they used stood to gain. In the United States, bioenergy industry officials express confidence that advances in technology, including higher crop yields and efficient production processes for second-generation agrofuels, will ensure that agrofuels do not increase food shortages, or starvation situations. Erik Fyrwald, group vice-president for DuPont Agriculture and Nutrition, stated that "technology can enable agriculture to continue to meet the food needs of the world very economically and, at the same time, play a very important role in meeting the world's needs in biofuels and biomaterials" (Brasher, 2007b).

In its annual report on global food situation, published at the beginning of October 2008, the FAO made a strong call for a revision of policies and subsidies of OECD countries regarding agrofuels, in order to keep the objective of world food security and to guarantee a sustainable environment. Jacques Diouf, FAO's director-general, stated that "the opportunities for developing countries to draw a benefit from the demand for agrofuels would be enhanced by the suppression of agricultural subsidies and trade barriers, which create an artificial market and are frequently only beneficial for the producers of OECD countries, to the detriment of developing countries". Underlining that agrofuel production had tripled between 2000 and 2007 and that it should continue to grow during the next decade, with an impact on the increase in the price of food commodities, FAO made a strong plea for the reduction of risks and for better sharing the advantage offered by agrofuels (Le Hir, 2008).

The first international conference on biofuels, attended by some 2,000 experts and political decision-makers from 40 countries, was convened in São Paulo from 17 to 21 November 2008. President Inacio Lula da Silva participated in the closure ceremony, while the US president whose presence was expected because of the cooperation agreement on bioethanol signed in March 2007 between Brazil and the United States, did not attend the conference. Amidst the world financial and economic crisis, the overall mood was not very optimistic according to the journalists who reported the debates. The precipitous fall of the price of the barrel of oil (under US$50) could explain the lesser support for agrofuels (Gasnier, 2008b).

While US$30 billion were expected to be invested in 2009 in the Brazilian ethanol industry, the Brazilian Union of Sugar-Cane Industries was requesting assistance from the federal government in order to overcome the financial and economic crisis. According to Marcos Jank - an executive of the Union - only falf of the 200 economic groups involved in the sugar industry would survive the heavy impact of the crisis (Gasnier, 2008b).

In addition, about a hundred of representatives of Brazilian and foreign social associations and movements, including Via Campesina (a non-governmental organization that defends the rights of small farmers, the principle of food sovereignty, and campaigns against genetically modified crops), voiced their concerns about the negative effects of sugar-cane cultivation and particularly the risks of a monoculture. In a final statement delivered to the organizers of the conference, these organizations stressed the threats to world food security, because industrial production of agrofuels is competing with food crops in terms of soils and waters (Gasnier, 2008b).

Jean Marc van der Weid, a specialist of family farming, quoted the case of São Paulo State, where two-thirds of bioethanol production are concentrated. In this State, the extension of sugar-cane fields between 1990 and 2003, has reduced the acreage devoted to maize, black beans, rice, wheat, citrus, coffee and cotton, according to this consultant of the Food and Agriculture Organization of the United Nations (FAO). Also environmentalist movements expressed their concerns about the encroachment of the Amazonian forests by crops and requested the Brazilian government to publish a map of the areas where sugar-cane should not be grown (Gasnier, 2008b).

Finally, Bruno Ribeiro, a lawyer specialized in labour rights in Recife, State of Pernambuco, declared that "the 500,000 cane-cutters suffered from the precarity of a seasonal job, sometimes in inhuman conditions". These conditions were also denounced by the Catholic Church of Brazil. However, observers noted that efforts are being made to improve these conditions and to cancel work contracts that do not respect the workers' rights (Gasnier, 2008b).

Despite all these criticisms, the studies distributed during the São Paulo conference highlighted that agrofuel production was expected to rise 191% from 2008 to 2015 and sugar-cane plantations were to increase their acreage. According to the National Institute of Space Studies, this acreage rose 15.7% in a year in the south of Brazil (Gasnier, 2008b).

Also, according to the French-Polish economist Ignacy Sachs, "the world financial and economic crisis may be a great opportunity for reviewing our parameters and for entering a new cycle based on biofuels" (Gasnier, 2008b).

Without overstating the role of agrofuels in the overall energy economy and balance, reasonable targets of production in those countries that chose the right crop species and bioengineering process, can contribute to the diversification of energy sources, particularly in transportation, without harming food production.

REFERENCES

- Alberganti, M. 2006. Produire plus de biocarburant avec du maïs OGM. *Le Monde*, 24-25 September 2006, p. 18.

- Allison, K.; Kirchgaessner, S. 2008. From hope to husk. *Financial Times,* 22 October 2008, p. 10.

- Armand, M. 2008. Limagrain renonce à expérimenter ses maïs transgéniques en France. *Le Monde*, 21 May 2008, p. 7.

- Betinardi Strapasson, A.; Mavignier de Araújo Job, L.C. 2007. Ethanol, environment and technology. Reflections on the Brazilian experience. *Revista de Política Agrícola* (Journal of Agricultural Policy published by the Secretariat of Agricultural Policy - Ministry of Agriculture, Livestock and Food Supply, Brasilia), special edition, no. 3, pp. 50-61.

- Bevan, M.W.; Franssen, M.C.R. 2006. Investing in green and white biotech. *Nature Biotechnology*, vol. 24, no. 7, pp. 765-767.

- Bezat, J.M. 2008. La baisse du pétrole pourrait soutenir une reprise économique. *Le Monde*, 24 October 2008, p. 12.

- Brasher, P. 2007a. Europe wants creative ways to boost biofuels industry. Continent's goal is to use 15 billion gallons of ethanol and biodiesel by 2020. *The Des Moines Register*, 18 October 2007, p. 8 ET.

- Brasher, P. 2007b. Food versus fuel? Countries debate priorities. *The Des Moines Register*, 18 October 2007, p. 8 ET.

- Brown, L.R. 2007. *Distillery demand for grain to fuel cars vastly understated. World may be facing highest grain prices in history*. Earth Policy Institute, available at: http://www.earth-policy.org/Updates/2007/Update63.htm

- Burke, D. 2007. Biofuels - is there a role for GM? *Biologist*, vol. 54, no.1, pp. 52-56.

- Caramel, L. 2008a. Les agrocarburants de deuxième génération ne seront pas prêts avant une décennie. *Le Monde*, 23 April 2008, p. 8.

- Caramel, L. 2008b. L'Union européenne fait marche arrière sur les agrocarburants. *Le Monde*, 8 July 2008, p. 7.

- Castello-Lopes, D. 2007. Des avions qui voleront avec de l'huile de palme. *Le Monde*, 1-2 July 2007, p. 14.

- Clavreul, L. 2007. Manger ou rouler: faut-il choisir? *Le Monde*, 7 April 2007, p. 31.

- Clavreul, L. 2008. L'essor des agrocarburants divise le monde agricole. *Le Monde*, 2 April 2008, p. 15.

- Clavreul, L.; Bezat, J.M. 2008. La France cultive l'ambiguïté sur les agrocarburants. *Le Monde*, 25 April 2008, p. 11.

- Energy Transition – Creative Energy. 2008. *Biomass, hot issue. Smart choices in difficult times*. Energy Tradition, Biobased Raw Materials Platform, Post Box 17, 6130 AA Sittard, Netherlands. energytransition@ senternovem.nl

- Ernsting, A. 2007. Agrofuels in Asia. Fuelling poverty, conflict, deforestation and climate change. *Seedling*, Grain's (Barcelona) quarterly magazine, July 2007, pp. 25-33.

- Faujas, A. 2007. L'éthanol contre l'éthanol. *Le Monde*, 14 February 2007, p. 33.

- Faujas, A. 2008. Obama et l'éthanol de maïs. *Le Monde*, 14-15 December 2008, p. 14.

- Foucart, S. 2007. L'essor des agrocarburants pourrait aggraver le réchauffement climatique. *Le Monde*, 25 September 2007, p.8.

- Gallois, D. 2008. Quand les avions volent au charbon liquéfié, aux micro-algues et à l'huile de noix de coco. *Le Monde*, 24 May 2008, p. 12.

- Galus, C. 2007. L'étude des termites pourrait permettre d'améliorer le rendement des agrocarburants. *Le Monde*, 23 November 2007, p. 8.

- Gasnier, A. 2006. La fièvre du biodiesel s'est emparée du Brésil. *Le Monde*, 13-14 August 2006, p. 10.

- Gasnier, A. 2007. Le Brésil mise sur un marché mondial de l'éthanol. *Le Monde*, 8 March 2007, p. 4.

- Gasnier, A. 2008a. L'expansion du pétrolier brésilien Petrobras ne fait que commencer. *Le Monde*, 12 June 2008, p. 12.

- Gasnier, A. 2008b. Une conférence internationale sur les biocombustibles réunit experts et politiques à Sao Paulo. L'éthanol sous le feu de la crise et des critiques. *Le Monde*, 22 November 2008, p. 4.

- Harrison, P. 2008. Oxfam blames biofuel for rising poverty. *International Herald Tribune*, 26 June 2008, p. 19.

- Hazell, P.; Pachauri, R.K. 2006. Bioenergy and agriculture: promises and challenges. Overview. In: Hazell, P. and Pachauri, R.K., *Bioenergy and agriculture: promises and challenges*, pp. 1-2. International Food Policy Research Institute, 2020 Focus 14.

- Hebebrand, C.; Laney, K. 2007. *An examination of U.S. and EU government support to biofuels: early lessons*. Washington, D.C., International Food and Agricultural Trade Policy Council, IPC Issue Brief 26, October 2007, 34 pp.

- Ihaddadène, L. 2007. Une plante du désert pour remplacer les puits de pétrole. *Le Monde*, 11-12 February 2007, p. 18.

- Jimenez, C. 2007. Scientists skim off a microscopic alternative to biofuels. *Financial Times*, 28 December 2007, p. 10.

- Kauffmann, S. 2008. Qui sème le biodiesel ne récolte plus de riz. *Le Monde*, 13 May 2008, p. 26.

- Kempf, H. 2007. Les promoteurs des arbres OGM veulent profiter de la vogue pour les agrocarburants. *Le Monde*, 21 April 2007, p. 7.

- Kempf, H. 2008. Sumatra. Le palmier à l'assaut de la forêt vierge. *Le Monde*, 9 January 2008, p. 20.

- Krieger, R. 2008. Successeur de Marina Silva au ministère de l'environnement, Carlos Minc veut protéger l'Amazonie des biocarburants. *Le Monde*, 21 May 2008, p. 5.

- Langellier, J.P. 2008. Le président Lula défend avec vigueur les biocarburants. *Le Monde*, 19 April 2008, p. 5. La croisade du Brésil pour l'éthanol. *Le Monde*, 11-12 May 2008, p. 2.

- Lavigne, P.A. 2007. Latin America - Threat, annoyance or land of hope. Ethanol in the Caribbean works on-and-off like a lightening bag, depending on trade, crops. *The Des Moines Register*, 18 October 2007, p. 6 ET.

- Ledford, H. 2006. Making it up as you go along. Chemists can make liquid fuel from biomass – or from coal. *Nature*, vol. 444 (7 December 2006), pp. 677-678.

- Le Hir, P. 2008. Des microalgues pour les biocarburants du futur. *Le Monde*, 23 October 2008, p. 4.

- Linoj Kumar, N.V.; Dhavala, P.; Goswami, A.; Maithel, S. 2006. Liquid biofuels in South Asia: resources and technologies. *Asian Biotechnology and Development Review*, vol. 8, no. 2, pp. 31-50.

- Margolis, M. 2007. Fast cars for the green set. *Newsweek*, 25 December 2006/1 January 2007, p. 73.

- Marris, E. 2006. Drink the best and drive the rest. Brazil's sugar-cane ethanol industry is the world's best and able to get better. *Nature*, vol. 444 (7 December 2006), pp. 670-672.

- Martin, A. 2008. Blaming biofuels for the spread of hunger. *The New York Times/Le Monde*, 26 April 2008, p. 4.

- Morceli, P. 2007. Brazilian alcohol. Prospects. *Revista de Política Agrícola* (Journal of Agricultural Policy published by the Secretariat of Agricultural Policy - Ministry of Agriculture, Livestock and Food Supply, Brasilia), special edition, no. 3, pp. 19-25.

- Palmer, K. 2007. The Cinderella plant. *Newsweek*, 19 February 2007, p. 39.

- Paranagua, P.A. 2007. Castro en guerre contre les biocarburants. *Le Monde*, 31 March 2007, p. 6.

- Pellet, J.D. & E. 2007. *Jatropha curcas. Le meilleur des biocarburants. Mode d'emploi, histoire et avenir d'une plante extraordinaire*. Paris, Ed. Favre, 64 pp.

- Perkins, J. 2007. Loophole hurt US ethanol prices. Brazilians cash in on customs law quirk; US won't say how much was paid. *The Des Moines Register*, 18 October 2007, p. 7 ET.

- Polgreen, L. 2007. Weed's potential as fuel encourages farmers. *The New York Times/Le Monde*, 29 September 2007, p. 5.

- Pons, P. 2008. Les Japonais disposeraient en 2009 d'un éthanol à base de riz. *Le Monde*, 2 October 2008, p. 5.

- Pontin, J. 2007. Tiny organisms may create better fuels. *The New York Times/Le Monde*, 9 June 2007, pp.1 and 4.

- Ragauskas, A.J. et al. 2006. The path forward for biofuels and biomaterials. *Science*, vol. 311 (27 January 2006), pp. 484-489.

- Raju, K.V. 2006. Biofuels in South Asia: an overview. *Asian Biotechnology and Development Review*, vol. 8, no. 2, pp. 1-10.

- Ram Mohan, M.P.; Thomas, G.T.; Shiju, M.V. 2006. Biofuel laws in Asia: instruments for energy access, security, environmental protection and rural empowerment. *Asian Biotechnology and Development Review*, vol. 8, no. 2, pp. 51-76.

- Ricard, P. 2008. Les eurodéputés veulent des agrocarburants respectant l'environnement et l'éthique. *Le Monde*, 13 September 2008, p. 8.

- Rohter, L. 2006. Fuel of future for U.S. now reality in Brazil. Investment in ethanol begins to pay off. *International Herald Tribune*, 11 April 2006, p. 13.

- Rosa e Abreu, F.; Nilton de Souza Vieira, J.; Yuri Ramos, S. 2007. National program for the production and use of biodiesel. Guidelines, challenges and prospects. *Revista de Política Agrícola* (Journal of Agricultural Policy published by the Secretariat of Agricultural Policy - Ministry of Agriculture, Livestock and Food Supply, Brasilia), special edition, no. 3, pp. 5-18.

- Rosenthal, E. 2007. Scientists are taking 2nd look at biofuels. Dutch efforts verge on nightmare. *International Herald Tribune*, 30 January 2007, pp. 1 and 12.

- Roux-Goeken, V. 2007. Des micro-algues à l'étude pour produire du biocarburant. *Le Monde*, 22 February 2007, p. 7.

- Sanderson, K. 2006. A field in ferment. To move US biofuels beyond subsidized corn will be a challenge. *Nature*, vol. 444 (7 December 2006), pp. 673-676.

- Schubert, C. 2006. Prairie dreams. *Nature*, vol. 444 (7 December 2006), pp. 674-675.

- Stolz, J. 2008. L'éthanol tiré du maïs fait polémique au Mexique. *Le Monde*, 9 August 2008, p. 14.

- The Authority of the House of Lords. 2006. *The EU strategy on biofuels: from field to fuel*. House of Lords, European Committee, 47th Report of Session 2005-2006, volume I: Report Published on 20 November 2006, HL Paper 267-I. Available at: www.publications.parliament.UK/pa/Id200506/Ids-elet/Ideacom/267/267i.pdf

- *The Economist*. 2006a. Green power in South-East Asia. Fuels rush in. *The Economist*, 26 August 2006, p. 44.

- *The Economist*. 2006b. Special report Synthetic biology. Life 2.0. *The Economist*, 2 September 2006, pp. 68-70.

- *The Economist*. 2007a. Peru. Sweet times. *The Economist*, 10 February 2007, p. 54.

- *The Economist*. 2007b. Biofuels. Burned by the sun. *The Economist*, 24 February 2007, p. 32.

- *The Economist*. 2007c. Iowa's ethanol economy. The craze for maize. *The Economist*, 12 May 2007, pp. 45-46.

- Van Gelder, Jan Willem; Kroes, Hassel. 2008. *European financing of agrofuel production in Latin America*. A research paper prepared for Friends of the Earth Europe. Profundo, The Netherlands, 47 pp. Website: www.profundo.nl

- Villano, M. 2007. Hawaii sees its crops as energy source. *The New York Times/Le Monde*, 9 June 2007, p. 4.

- Wani, S.P.; Osman, M.; D'Silva, E.; Sreedevi, T.K. 2006. Improved livelihoods and environmental protection through biodiesel plantations in Asia. *Asian Biotechnology and Development Review*, vol. 8, no. 2, pp. 11-13.

- Wasik, J.F. 2007. In ethanol debate, don't forget realities. *International Herald Tribune*, 24 July 2007, p. 17.

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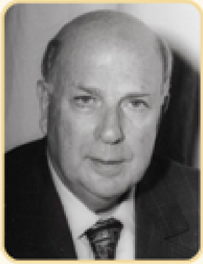

Albert Sasson, M.Sc., D.Sc. (University of Paris), is a founding member of the Hassan II Academy of Science and Technology. He has had a distinguished scientific career as a Professor and Dean of the Faculty of Sciences of Rabat, Morocco; and thereafter at the United Nations Educational, Scientific and Cultural Organization (UNESCO, Paris). He was Assistant Director-General of UNESCO and Special Advisor to the UNESCO Director-General from 1993 to 1999.

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About the book

Most of global energy consumption is currently met by fossil fuels, particularly oil and natural gas, the prices of which have been increasing steadily. Most countries are therefore trying to save energy and to diversify their energy sources, and in this respect to increase the share of renewable sources, e.g. solar, wind, hydroelectric energy. They are also looking at agroenergy as an attractive prospect.

Bioethanol and biodiesel are the main types of agrofuels, derived from the fermentation by yeasts of feedstocks rich in sucrose (sugar-cane, sweet sorghum, molasses) or in starch (maize and other cereals, cassava), and from the esterification of vegetable oils (e.g. palm, rapeseed, soybean and castor bean oils) or animal fats or used frying oil, respectively. Both liquid agrofuels are used for transport as mixtures with gasoline and diesel.

Although agrofuels currently contribute to a small fraction of the energy consumed in transport worldwide, they are considered by many countries as means to decrease their dependence on oil and to improve their energy security. And indeed plantation of energy crops, biorefineries and a whole industry are expanding worldwide. Many investments are being made and industrial conglomerates are being consolidated.

In addition to briefly reviewing the prospects for the transition from non-renewable carbon and energy resources to renewable bioresources, the book presents the United States and European Union's agrofuel policies, the situation of bioethanol and biodiesel production and industry in the United States, Brazil, Europe, Latin America and the Caribbean, Asia and sub-Saharan Africa, as well as the potential of second-generation agro-and biofuels, such as «cellulosic» ethanol, biokerosene and fuels possibly derived from microalgae.

Agrofuels have raised controversial issues about their real contribution to improving the energy equation, reducing carbon dioxide emissions significantly, and about becoming a threat to food supply. Beyond the polemics, and while acknowledging that agriculture must above all continue to feed the world, the book advocates that the production of agrofuels should be reviewed country by country, in order to set reasonable targets of production, particularly in those countries that choose the most appropriate energy crop and bioengineering process without harming food production and farmers' income.

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