Global Biofuel Production Trends and Possible Implications for Swaziland[1]

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I. INTRODUCTION

Geopolitical tensions, energy price increases, uncertainties about remaining reserves of fossil fuels and the environmental impact of using such fuels even if they exist, have provided the impetus for a strong interest in biofuels in many parts of the world. Biofuel production, seen as a clean alternative to fossil fuels, have been aided in several countries by generous government support both at the border as well as in the form of direct subsidies to the sector and related regulatory framework promoting and facilitating their use in the domestic transportation sector.

The contribution of biofuels as an alternative energy source is currently limited but this is rapidly changing. However, there are important questions about the energy efficiency of the different feedstocks, the environmental benefits from the life cycle of biofuel production and use, the economic rationale of these alternative sources of energy, and important ethical issues in view of the inextricable link of biofuels to agriculture[3]. Nearly all commercially manufactured biofuels use as feedstocks agricultural crops such as sugarcane, sugar beets, maize, cassava, wheat, barley, rapeseeds, soybeans, and palm oil[4]. In view of this, developments in the biofuel sector, and related government policies promoting it, affect agricultural and food markets, and raise important questions about food security.

Sugarcane is one of the most important first generation feedstocks used in the production of biofuels and massive use of sugarcane for ethanol production has important implications for this commodity and the countries depending on it.

Swaziland is an exporter of sugar, mostly under preferential terms, and a net importer of basic food commodities. To the extent that there is a substantial shift of global agricultural resources to sugar and other biomass used for energy production, world prices of food commodities would increase and Swaziland, as a net food importer, would be negatively affected. However, increasing use globally of sugar for ethanol production would have a positive impact on world sugar prices and thus, at the margin, on Swaziland's export earnings. Swaziland could also benefit from opportunities for bioenergy production for domestic use or for export.

The paper provides first a short resume of the nature of biofuels and their classification. It then reviews in section III the various stated objectives for biofuel production and discusses their rationale. In section IV the paper focuses on ethanol and reviews recent trends in global production, utilization and trade as well as the outlook for the next decade taking into account policy objectives of countries with substantial ethanol production programmes. The possible effects of trends in the biofuels sector on food prices are discussed in section V. Section VI of the paper assesses the implications of these developments for a sugar

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[2] The views expressed in this paper are those of the authors and do not necessarily reflect official views of the Food and Agriculture Organization. The authors wish to thank Themba N. Masuku, FAO Geneva Office, for his helpful comments. Thanks are also due to Abby Abbassian and Adam Prakash, Trade and Markets Division, FAO Rome, for providing statistics and analysis of Swaziland's food security situation.

[3] For example, 'There is a great danger for the right to food by the development of biofuels', claims Jean Ziegler, UN special rapporteur on the right to food, *PlanetArk*, 15/6/07.

[4] It does not matter whether a feedstock competes with direct human consumption, i.e. whether it is edible or not. Competition only takes place for the resources used in production. For example, if there is a food-based feedstock (say sugarcane) that takes only half of the area that a non-food feedstock (say jatropha) would take to produce the same quantity of biofuel energy, this would lift aggregate food prices less than if one were to grow only sugarcane and no non-edible jatropha. Jathopha's comparative advantage as a biofuel feedstock precisely lies in its low resource requirements, which allows the crop to be grown under agro-ecological conditions (low water needs and soil quality), where hardly any other crop can be grown, i.e. without significant competition for resources.

producing/exporting country such as Swaziland which also imports an increasing share of its food and energy needs, and possible policy responses are discussed to mitigate negative effects and take advantage of new opportunities. The paper closes with concluding remarks in section VII.

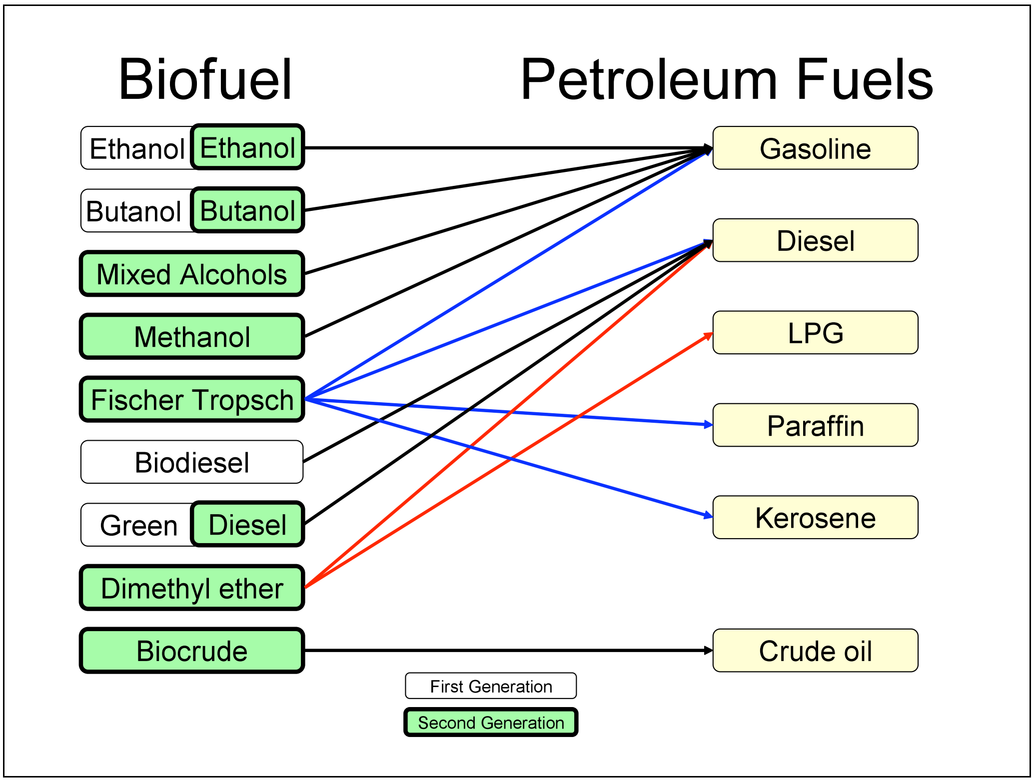
II. BIOFUELS: A SHORT PRIMER

Biofuels are liquid, gaseous or solid hydro-carbon fuels derived from biomass. Biomass includes any organic matter that is available on a renewable or recurring basis, such as agricultural crops and trees, wood and wood wastes and residues, plants (including aquatic plants), grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials. Although technically also derived from biomass (the biomass from which they are derived is from earlier geologic eras in the Earth's history), fossil fuels are not considered 'biofuels' within the common-use meaning of the term.

Biomass is generated by the process of photosynthesis which stores the sun's energy by binding hydrogen to carbon-backboned long-chain molecules. The stored energy is then recovered by the process of oxidization, i.e. the combination of oxygen with these carbohydrates in the process of plant or animal metabolism or by burning the carbohydrate based compounds. Metabolism or combustion recombines the hydrogen with oxygen to create water and carbon to oxygen to form carbon dioxide, which is then available to be recycled by plants once again. This carbon cycle implies that the use of biofuels has no net carbon release impact on the environment, aside from the fossil fuels required in the production of biomass and its conversion to biofuels.

Ethanol and biodiesel (both liquid) are the two most important biofuels today and they are of primary interest for transportation. However, the biofuels list is much longer (see Figure 1 which also shows the correspondence between biofuels and the petroleum products which they can substitute).

Figure 1. Biofuels and corresponding petroleum fuels[5]



[5] E. D. Larson, "Biofuel Production Technologies: Status and Prospects", UNCTAD Ad hoc expert group meeting on *Biofuels: Trade and Development Implications of Present and Emerging Technologies,* 19 June 2007, Geneva

Biofuels are typically used in low-percentage blends, in the neighborhood of 5 to 10% mixed into petroleum fuels, but they can also be used in pure form. Ethanol is dehydrated into a form called anhydrous ethanol before it is blended into gasoline, which adds to the cost and to the energy used in making the biofuel[6]. Biofuel blends are designated by the amount of the biofuel contained in conventional petroleum products. Letters "E" and "B" are used for ethanol-containing and biodiesel-containing fuels, respectively. For example, the term E10 is used to designate a mixture of 10% ethanol and 90% gasoline. Similarly, B5 is a blend containing 5% pure biodiesel and 95% petroleum diesel, and so on.

Biofuels are divided into two broad categories, depending on the type of biomass used for their production: first generation and second generation (Figure 2). **First generation biofuels** are derived from first generation feedstocks, i.e. biomass sources that have either high sugar or starch contents (starch can be relatively easily converted to sugar) or those which have high oil content. Examples of the first source are: sugarcane, beets and cassava, and grains such as corn and wheat. All of these feedstocks can be converted into ethanol via either biologic (yeast or bacterial) means or chemical means. Examples of feedstocks with high oil content include rapeseed, soybeans, cotton seed, sunflower seed, palm, jatropha, coconut and other tropical oils. The oils are extracted generally by chemical means and can be used directly as fuel or they can be further processed to produce biodiesel.

Second generation biofuels, are derived from second generation feedstocks, i.e. biomass not rich in either sugars or oils. Such feedstocks include cellulose, hemi-cellulose and lignin, i.e. the "woody" parts of grasses, bushes, trees and similar plants. These substances are difficult to break down into their component sugars and require extensive and expensive processing prior to being converted into biofuels. Much research is being devoted into new technologies for the enzymatic breakdown of these substances into their component sugars. However, these technologies are not yet widely available for commercial use[7] due to their high costs, although costs are declining and the U.S. Department of Energy (DoE) estimates that "improvements to enzymatic hydrolysis could eventually bring the cost to less than 5¢ per gallon, but this may still be a decade or more away". Other older approaches, both pyrolytic (heating biomass in low oxygen conditions to create liquid, gaseous or solid fuels) and chemical, such as the Fischer-Tropsche process, are also being revived and further developed[8].

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[6] However, vehicles that are manufactured to run on pure ethanol can use hydrous ethanol, which contains about 4–5% water.

[7] There are some initial commercial ventures of using hemi-cellulosic feedstock: Probably the most important is IOGEN, a company located in Ottawa, Canada. IOGEN's processing know-how has been patented under the name EcoEthanol™ and represents a combination of thermal, chemical and enzymatic conversion of wheat straw. The company is generally seen as the technology leader in the area of enzymatic lignocellulosic ethanol production and has been benefiting from inputs by and commercial interest of Shell, Petro-Canada and the government of Canada. Goldman Sachs recently acquired a stake in the company. Another is Dedini, a Brasilian cane processor that developed a patented process for the hydrolysis of bagasse and its final conversion to ethanol. The process is known as "Dedini Hidrólise Rápida" (DHR), its development was sponsored by the government of Brazil and the World Bank. A semi-commercial plant was built in 2002 in Pirassununga and produces about 5000l ethanol per day. The main purpose of the Pirassununga plant, however, was to deliver the operational parameters for a fully commercial plant. In addition, it will also help gather experience for converting cane *straw* to ethanol. Bagasse and straw conversion could significantly boost Brazil's ethanol production without any additional need to increase the country's cane acreage or without further increasing the already staggering water consumption. If all of the country's Bagasse was converted to ethanol, this would increase Brazil's ethanol output by 82.6%. If also cane straw could be used, an additional increase of a similar magnitude might become possible. The use of bagasse for ethanol production is limited by the fact that bagasse is also the main feedstock for electricity production and co-generation in all modern sugar mills. Its use for ethanol production would thus come at high opportunity costs. The use of straw could become an increasingly interesting and even a pressing issue when the burning of the cane fields, a common practice to ease harvesting, will be banned by law as of 2010. The use of sugar and bagasse make sugar cane the most competitive feedstock today. The use of straw in addition, will make it de facto the first 2nd generation bioenergy crop.

[8] "WTO Disciplines and Biofuels: Opportunities and Constraints in the Creation of a Global Marketplace", IPC Discussion Paper, October 2006.

Figure 2. First and second generation biofuels and corresponding feedstocks[9]

Biofuel Classification

First Generation (from sugars, grains, or seeds)

– Alcohols (ethanol, butanol)
  - From grains or seeds: corn, wheat, potato
  - From sugar crops: sugar beets, sugarcane

– Pure plant oils (straight vegetable oil)

– Biodiesel (fatty acid methyl ester; fatty acid ethyl ester)
  - rapeseed (RME), soybeans (SME), sunflowers, jatropha, coconut, palm, recycled cooking oil

Second Generation (from lignocellulose: crop residues, grasses, woody crops)

– Biological fuels
  - Ethanol (or butanol) via enzymatic hydrolysis

– Thermochemical fuels (most made via "gasification")
  - Fischer-Tropsch liquids (FTL)
  - Methanol, MTBE, gasoline
  - Dimethyl ether (DME)
  - Mixed alcohols
  - Green diesel

II. WHY BIOFUELS?

Production of renewable energy, in general, and biofuels in particular, has risen rapidly to the top of the policy agendas in many countries. The growing interest in biofuels is driven principally by three factors: First, concerns about energy security, in particular the finite availability of global crude oil supplies and the risks associated with reliance on oil imports from unreliable suppliers; second, concerns about the environment, especially Green House Gasses (GHG) emissions which are considered as the main cause of climate change; and third, agricultural policy concerns, in particular the need to create new demand for agricultural produce and hence boost farm revenues, against the backdrop of long-term declining prices for agricultural commodities and increasing obligations to reduce government support under the WTO negotiations on agriculture.

…enhancing energy security?

The most frequently cited rationale for biofuel production and related government support to the sector is energy security. The supply of fossil fuels is finite and these nonrenewable resources will eventually be exhausted, requiring substitution with alternative sources. Other security concerns relate to disruptions to oil supplies due to political events and wars, short-term adverse weather conditions and unexpected infrastructure breakdowns, policy decisions by the Organization for Petroleum Exporting Countries (OPEC) to limit supply, etc. These energy security concerns have led to a desire for less dependence on imported petroleum, and greater self-sufficiency in fuel supply in the form of domestic production of biofuels.

But what is the potential of biofuel contribution to energy security? At present their contribution to total global energy use is very small. In 2006 they provided only about 1.1EJ or 1.3% of road transportation needs and thus less than 0.3% of total energy supplies (Table 1). As for the future, various assessments of global and regional potential of bioenergy production, give an idea of the magnitude of this potential.

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[9] Larson (op cit).

Table 1: Agricultural and energy markets, potentials and actual use[10]

			[9]Exajoule/a [10^{18} Joule]/a			million ha
Energy source:	Potential and actual use	Year	World	OECD	non-OECD	World
All sources (TPES)		1973[2]	253	157(62.3%)	95(37.7%)	
		2004[2]	463	231(49.8%)	232(50.2 %)	
		2030[2]	691	285(41.2%)	406(58.8 %)	
		2050[2]	>850			
Biomass	Actual use	2004[2]	49[11]	8	41	
	Theoretical potential		>>2000	Global photosynthesis: ~ 3150 EJ		
	Technical potential	1990[1]	225	48[12]	177[12]	
		2050[1]	400	80[12]	320[12]	
	Economic potential	2050[1]	158			
Biofuels	Ethanol[7] (actual)	2004[3] 2006	0.84 1.01	0.34	0.51	9.52[4]
	Biodiesel[7] (actual)	2003[3]	0.06	0.04	0.02	0.47[4]
	Potential[1]	2050[1]	53[10]			
	Use	2030	4.8(8.4)[13]	2.3(4.0)[13]	2.5(4.4)[13]	
Resources:			million ha			
Agricultural land[8]	Used for agriculture	1997-99	1506	658	848	850[4/5]
	Total suitable		4188[8]	1406[6]	2782[6]	
	Used for biofuels	2006	14			~1% of land
		2030	32.5 (57)[13]			~2% of land

1.) Potential based on Schrattenholzer and Fischer, IIASA, 2000
2.) Based on IEA 2004b: Key energy statistics, 2006 (TPES), EIA (US) projections for 2030 are 761 EJ (in terms of consumption)
3.) Derived from http://www.earth-policy.org/Updates/2005/Update49.htm, Earth Policy Institute
4.) Assuming an average yield per hectare for ethanol of 4200 l (3000 l US maize, 5500 l Brazil cane, 6900 l France sugar beet) and of 3800 l/ha for biodiesel (average palm oil, rapeseed oil, etc.). Most recent yields are about 10% higher for cane and 20% higher for maize.
5.) 850 million ha would be required to meet 2002 road transport fuels needs (77 EJ) at current yields (l biofuel/ha), technology, and crop composition.
6.) Area for developed and developing countries, not OECD and non-OECD
7.) Assuming an energy content of 34 MJ/l for biodiesel and 21.1 MJ/l for ethanol
8.) Bruinsma (ed), World agriculture: towards 2015/2030, An FAO Perspective, 2003, total suitable land for rainfed agriculture
9.) 23.8845 Mtoe = 1 EJ
10.) IEA (2004a), "Biofuels for Transport", table 6.8.; road transportation in 2030 about 120 EJ; total 132 EJ; EIA.
11.) 15-60 EJ: most biomass fuels are not traded on world markets, estimates of consumption are highly uncertain.
12.) Based on regional estimates from Schrattenholzer and Fischer, IIASA, 2000
13) The IEA Energy Outlook 2006 assumes a 4% share in road transportation in 2030 in the reference case, 7% in the alternative scenario

[10] Schmidhuber, J, "Impacts of an increased biomass use on agricultural markets, prices and food security: A longer-term perspective", paper prepared for the "International symposium of Notre Europe", Paris, 27-29 November, 2006.

At the most general level, the global bioenergy potential is defined by the total amount of energy produced by global photosynthesis. It is estimated that plants collect a total energy equivalent of about 3150 Exajoule[11] per year or nearly seven times the global current amount of energy used, estimated at about 460 EJ in 2004. While impressive, this photosynthesized energy is only a theoretical number. Only a fraction of it is technically available and yet a much smaller fraction is economically viable.

The **technical** bioenergy potential is essentially that part of the theoretical potential that can be possibly harvested and thus be harnessed for practical energy use. As assessed by a number of studies that have gauged the volume of biomass that can technically contribute to global energy supplies, that technical potential is a relatively small fraction of the theoretical one. Fischer and Schrattenholzer, for instance, estimate that the global technical potential of biofuels could be about 400 EJ/a by 2050, or less than one-fifth of the theoretical potential[12].

The most relevant concept, however, is the **economically viable** biofuel potential. The crucial determining factor here is the cost of producing biofuels compared to the price of fossil energy. Only part of the technical potential can compete with fossil energy after all costs for planting, harvesting, transport and processing have been accounted for. The global amount of biomass that could be economically harvested by 2050 has been estimated by Fischer and Schrattenholzer to be in the range of 158 EJ/a. At current conversion technologies and efficiencies the 158 EJ/annum would yield only about 53 EJ/annum in terms of useable biofuel equivalent products[13]. This quantity of biofuels would represent some 6.2% of the projected energy needs in 2050. While the contribution of biofuels is not insignificant, it is far from being a source of energy that could provide a real alternative to global dependence on fossil fuels.

What is also important to note is the regional differences in the present and future biomass and biofuel potential. In general, biomass is a more important contributor to energy supplies in developing countries[14] where it accounted for nearly 19% of their total primary energy supplies (TPES) in 2004 (Figure 3), equivalent to 41 EJ, while it is much less important, both in absolute terms and as a share of total energy supply, in OECD countries. On average in 2004, biomass accounted for 3.4% of TPES in the OECD countries and in nearly all of them it accounted for less than 5%.

While the assessed future biofuel potential of 53 EJ/a is not further broken down by OECD and developing countries, if the technically available biomass is taken as a guide (80% of which originates in developing countries in 2050), it follows that the largest part of the potential of biofuels production is in the developing countries and if harnessed locally could represent a relatively greater share of their energy needs than what is implied from global averages.

Aside from the economic potential that this represents for several developing countries, another positive result of exploiting their relatively large biomass potential is for domestic use as cooking fuel. It is estimated that three billion people in developing countries cook with solid fuels today with major health consequences. The World Health Organization identifies indoor air pollution from cooking as the second highest environmental risk factor (after unsanitary water) contributing to global burden of disease (a conservative estimate is 1.6 million premature deaths/yr). Biofuels such as biogas, vegetable oils, or ethanol could replace such hazardous solid fuels. In India for instance, biogas has already replaced fuel wood and cow dung as the main cooking fuel, in Mali, jatropha oil is used as a fuel to run electricity generators for individual or communal households. Some 4 to 5 EJ/yr of biofuel would be sufficient to address this problem

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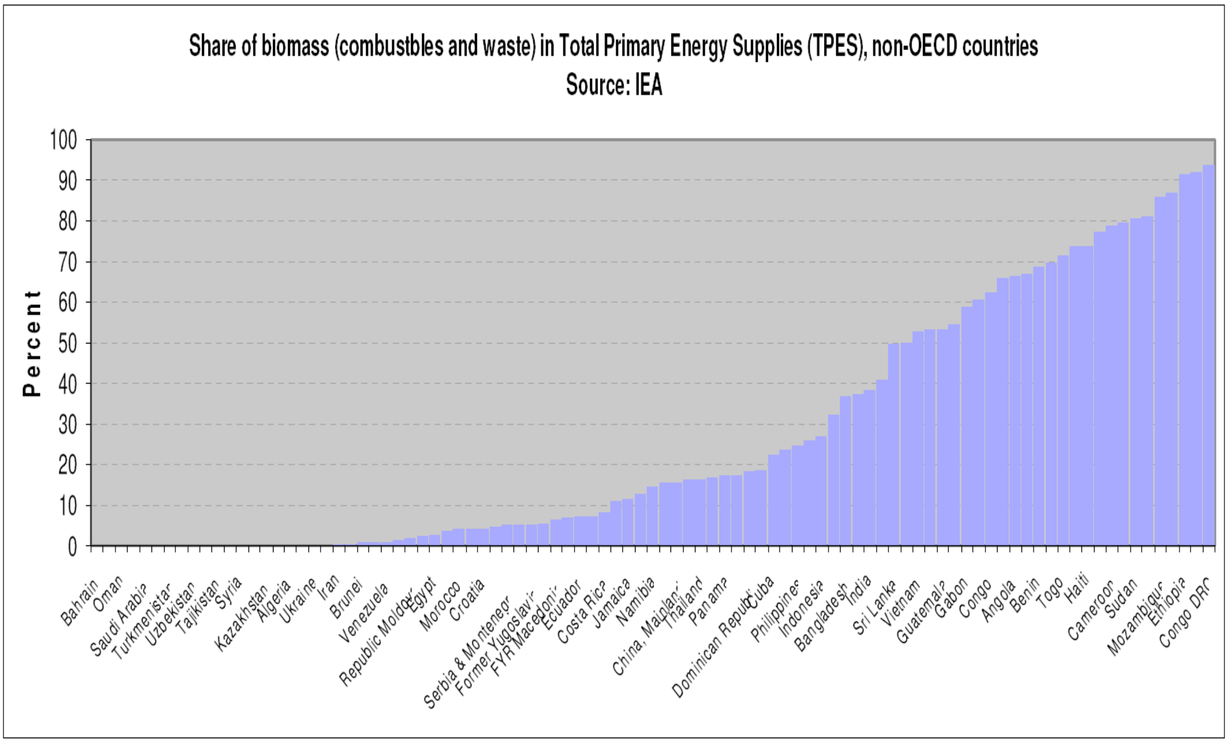
11 One Exajoule (EJ) is equal to 10^{18} Joule.
12 Fischer, G. and Schrattenholzer, L. "Global bioenergy potentials through 2050", in Biomass and Bioenergy 20, Elsevier, 2001.
13 This could increase considerably assuming improved conversion rates from second-generation biofuels and lower production costs.
14 The importance of biomass varies widely across the various developing regions. Whereas biomass is entirely irrelevant for all oil and/or gas rich countries in the Near-East/North-Africa region, it is often the most important source of energy in most countries in sub-Saharan Africa. In some of these countries, bioenergy accounts for more than 90% of the TPES, examples are Tanzania (92%), Ethiopia (92.1%) and the Democratic Republic of Congo (93.5%) (for details see Figure 3). However, the high biomass use in developing countries is often based on low-end products like charcoal, fuel wood or even cow dung and is often associated with environmental damage (deforestation) and health problems (fuel wood in India).

(this is less than 10% of the estimated economically viable global biofuel production, and most of the potential, as discussed above, is in developing countries).

Figure 3: The share of current bioenergy use in developing countries



... achieving a positive energy balance?

Table 2 gives an idea of the quantity of different crops required to produce 100 litres of ethanol and Figure 4a ethanol yields per hectare for different countries and feedstocks. While these numbers are of interest, they do not say anything about the energy balance of the processes involved in producing ethanol. Production of biofuels requires energy for planting, harvesting, transport and processing of biomass. A necessary, but not sufficient condition for ethanol economic feasibility is that the energy produced would be greater than the energy that is used in this process. This energy balance is obviously very much dependent on the type of biomass, the production system, technologies used, etc.

Figure 4b provides a broad picture of such energy balances for the different feedstocks used on ethanol production. The differences between them are large. Corn in the US and wheat and sugar beets in the EU barely exceed the 2:1 ratio, while the real champion is sugarcane (Brazil) with an over 8:1 ratio (although this ratio may not apply everywhere in Brazil nor in other sugarcane producing countries).

... addressing environmental concerns?

Biofuels have several potential environmental advantages. The most important is the reduced GHG emissions relative to fossil fuels, since biofuels are derived from plants which absorb carbon dioxide (CO2) and convert it into carbohydrates for their growth. However, the degree of reduction varies markedly with feedstock and the production technology used. Figures from different studies on life cycle CO2 balance for ethanol is shown in Table 3. That Table gives an indication of the degree of divergence of different findings, with some studies even coming up with opposite signs for the same feedstock.

Table 2. Ethanol conversion factors[15]

To produce 100 litres of ethanol* it takes:	
4,000 l	of cheese whey
1,400 kg	of sweet sorghum
1,270 kg	of sugar cane
1,250 kg	of Jerusalem artichoke
1,030 kg	of sugar beet
850 kg	of potatoes
545 kg	of cassava
385 kg	of wood
360 kg	of molasses
268 kg	of maize (wet milling)
258kg	of maize (dry milling)
260 kg	of wheat
230 kg	of millet
225 kg	of paddy rice
*) average values; actual yields may vary depending on production process and feedstock quality.	

Figure 4a. Ethanol yields per area harvested (litres per ha - 2001/05 average)[16]

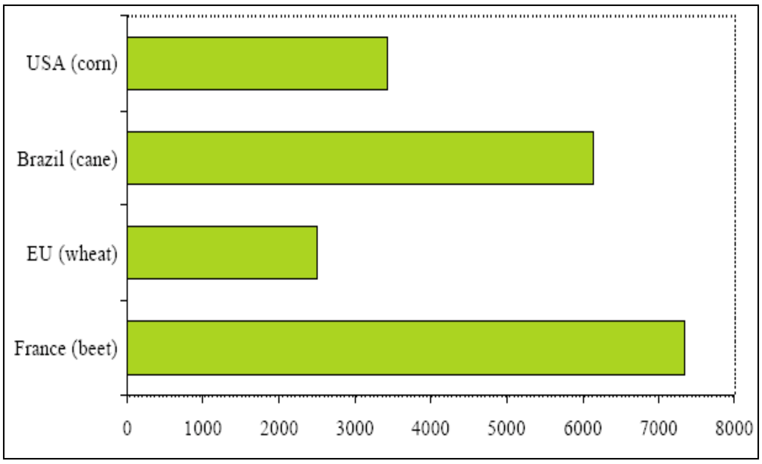
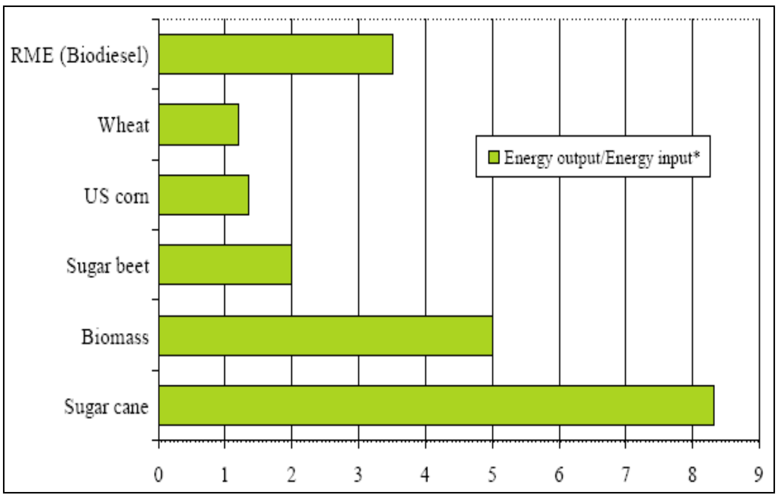


Figure 4b. Energy balance[17]



[15] "World Ethanol Markets, A special Study: The Outlook to 2015", F.O. Licht, 2006, UK (Table 1.6).
[16] F.O. Licht, op. cit.
[17] F.O. Licht, op. cit.

Figure 5 provides ranges of costs for one ton reduction in CO2 achieved through the life-cycle process of producing and using different feedstocks. For instance, Armstrong et al. report CO2 savings of 0.5kg/l ethanol based on wheat as a feedstock, and 0.65kg CO2 savings for every litre of ethanol produced on the basis of sugar beets[18]. A similar value is reported in a study by General Motors (0.69 kg/l) also based on sugar cane as a feedstock. Higher savings are possible, particularly where crop yields are higher. Schmitz reports that both sugar beets and wheat can help avoid 1.5kg CO2/l[19]. More than 2kg are possible where ethanol is produced in efficient farming systems on the basis of sugar cane[20].

There seems to be some consistency in these findings that ethanol from maize in the US does not give a significant environmental benefit, and can even increase GHG emissions. Also, the environmental benefit of ethanol produced from grain in the EU is questionable (in view of the very high cost in reducing GHG emissions). On the other hand, ethanol from sugarcane can yield significant GHG emission savings and the cost of doing so is significantly lower than that of any other feedstock. The CO2 balance is outright negative where biofuel feedstocks production (notably for palm oil plantations) causes deforestation of native rainforests; the CO2 released in the degradation process of the soil organic matter is typically a multiple of what the palm oil production can sequester over its entire lifecycle.

In general, the findings indicate that it is not to be taken for granted that there are necessarily environmental benefits from all biofuels and this claim needs to be justified on a case by case basis after a careful balance accounting for all direct and indirect environmental effects, including also changes in land use patterns, burning and clearing existing CO2 sinks (rainforests), soil erosion, water depletion, etc. Only location, feedstock and process-specific lifecycle analysis (LCA) can provide an objective picture as to how environmentally friendly a particular biofuel is being produced.

Table 3. GHG reduction comparisons[21]

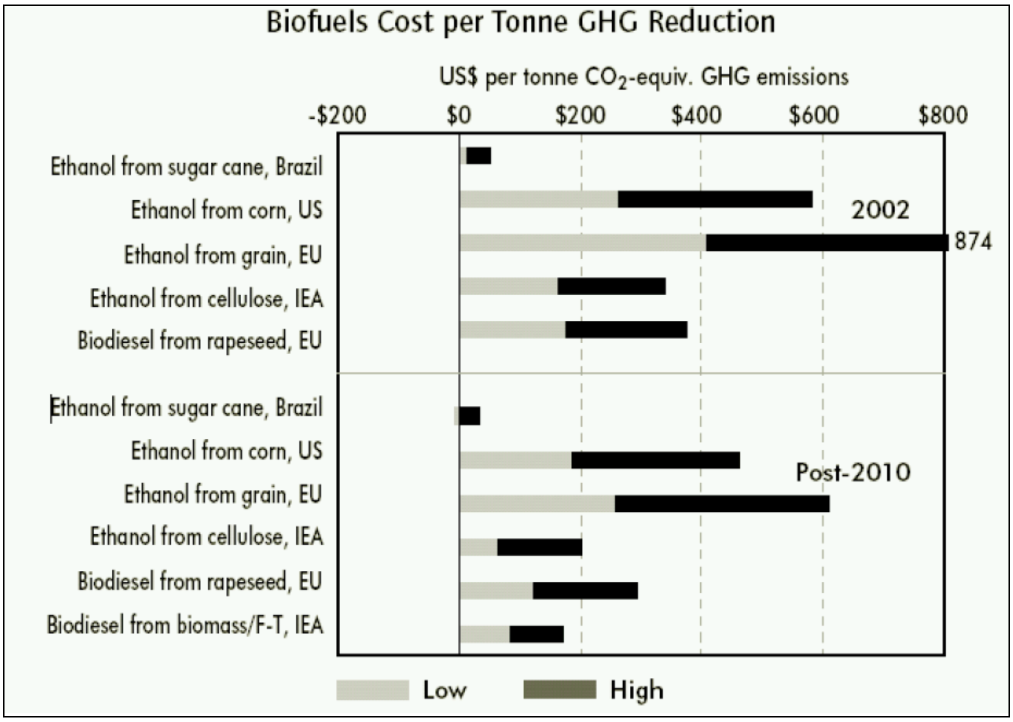
Table 1.1 Change in Lifecycle Greenhouse Gas Emissions per Kilometer Traveled by Replacing Gasoline with Ethanol in Conventional Spark Ignition Vehicles

Feedstock	*Location*	*Change*		*Source*
Wheat	UK	-47%		Armstrong et al. 2002
Sugar beet	North France	-35%[a]	-56%[b]	Armstrong et al. 2002
Maize, E90	USA, 2015	10%		Delucchi 2003
Maize, E10	USA	-1%		Wang et al. 1999
Maize, E85	USA	-14%[c]	-19%[c]	Wang et al. 1999
Cellulose, E85	USA, 2005	-68%[c]	-102%[c]	Wang et al. 1999
Molasses, E85	Australia	-51%[d]	-24%[d]	Beer et al. 2001
Woodwaste, E85	Australia	-81%		Beer et al. 2001
Molasses, E10	Australia	1%[d]	3%[d]	Beer et al. 2001
Sugar, hydrous ethanol	Brazil	-87%[e]	-95%[e]	Macedo et al. 2004
Sugar, anhydrous ethanol	Brazil	-91%[e]	-96%[e]	Macedo et al. 2004

Note: Percentage changes are for neat ethanol unless indicated otherwise.
[a] Average
[b] Best case
[c] A range given in the study report
[d] Different assumptions about credits for by-product
[e] The first uses average values of energy and material consumption, the second represents best practice

[18] Armstrong, A.P.; et al. (2002): Energy and greenhouse gas balance of biofuels for Europe – an update. CONCAWE, report no. 2/02, Brussels 2002.
[19] Schmitz, Norbert (Ed.) : Bioethanol in Deutschland. Verwendung von Ethanol und Methanol aus nachwachsenden Rohstoffen im chemisch-technischen und im Kraftstoffsektor unter besonderer Berücksichtigung von Agraralkohol. Schriftenreihe „Nachwachsende Rohstoffe" Band 21, Landwirtschaftsverlag, Münster 2003.
[20] MEÓ: Innovationen bei der Bioethanolerzeugung und ihre Auswirkungen auf Energie- und Treibhausgasbilanzen - Neue Verfahren, Optimierungspotenziale, internationale Erfahrungen und Marktentwicklungen - für die Fachagentur Nachwachsende Rohstoffe e.V., FKZ 22007403 Endbericht, 2004.
[21] Kojima, M. D. Mitchell and W. Ward, "Considering Trade Policies for Liquid Biofuels", ESMAP, World Bank, May 2007.

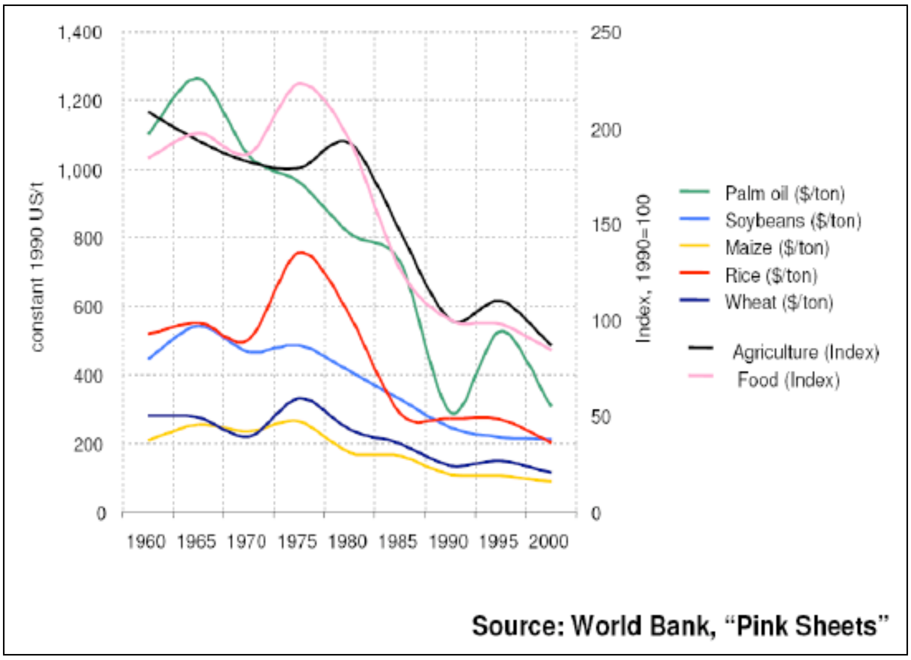
Figure 5. Cost comparison of different biofuels in CO_2 reduction[22]



... boosting domestic farm revenues?

For decades, global agricultural markets have been characterized by a steady decline of real prices of agricultural commodities. From 1973 to 2000, for instance, food prices fell by about 60% and agricultural prices by about 55% in real terms (Figure 6). While the decline over the last four decades was particularly pronounced, it was part of a longer term trend observed during the entire 20th century.

Figure 6. Real prices for food and agriculture



[22] Coelho, S. T. "Biofuels: Advantages and Trade Barriers", UNCTAD 2005.

This secular decline in real prices has its origin on two main factors: on the supply side, rapid technological progress in agriculture meant lower unit costs of production; on the demand side, a slowdown in demand growth (due to population growth slowdown) and a saturation of demand, first in developed countries and increasingly in many developing countries. Thus, growth rates of world demand steadily declined and are projected to fall further (from 2.2% annually for the period 1969-1999 to 1.6% to 2015 and 1.4% for 2015 to 2030). FAO's long-term outlook to 2050 suggests that the decline in demand growth will become even more pronounced after 2030, with growth rates for aggregate food declining to 0.9% annually for the world as a whole and 1.1% for the developing countries [23].

Against this backdrop of long-term declining agricultural commodity prices and with the prospects for the future also not encouraging, the potential extra demand for feedstocks used in energy production has been seen as an unexpected blessing by some. However, the size of this potential will crucially depend on how much agricultural produce can be used competitively for energy production. At current energy prices, some agricultural feedstocks have indeed already become competitive sources of energy, at least under certain production environments. The direct and indirect government support (financial and regulatory) has raised demand for other less competitive feedstocks. As a consequence, demand for these feedstocks has expanded and already supports prices for these commodities. Maize is a case in point. Because of the substantial demand for US corn in ethanol production, maize prices in the world market have nearly doubled in the last year and area planted on corn in the US increased considerably (see section IV of the paper).

Policies on ethanol production have already had an impact on agricultural prices by effectively providing a support level through the new demand for such commodities used for biofuel production. To the extent that this new demand continues (something that depends on the price of energy itself and the willingness of governments to subsidize bioenergy production programmes), it would reduce the pressure for agricultural support in the developed countries, presently providing large direct and indirect subsidies to their farmers. In effect, support to farmers would be given indirectly through the support to the biofuel sector and the attendant strengthening of prices of the agricultural commodities used in biofuel production.

…but what about competitiveness and at what price of energy?

Figure 7 shows the parity prices (expressed in either US$/bbl of crude oil or in US$/l of petrol) of different feedstocks used in biofuel production. The parity price of a given feedstock is that point where total costs for biomass-based energy production (i.e. cost of feedstock, upstream and downstream transport, conversion, wages, capital) are covered fully by revenues from sales of bioenergy (ethanol, biodiesel, etc.). In other words, this is the point where bioenergy producers break even. It follows that for a particular feedstock to be competitive, the price of fossil fuel has to be above the parity price for that feedstock.

The most competitive feedstock is clearly sugarcane in Brazil's south-centre region at US$28/bbl, while the average for Brazil as a whole stands at US$35/bbl. Next in the competition ladder is large scale cassava-based ethanol production in Thailand at US$38/bbl for, followed by palm oil-based biodiesel in Malaysia at US$45/bbl, maize-based ethanol in the US at US$58/bbl, and up to nearly US$100/bbl for certain fuel products in Europe. It is important to note that these parity prices have been calculated for very specific production and conversion technologies (as well as based on the exchange rate to the US$ that applied for the underlying year of the calculations) and may thus not necessarily apply to the same or similar feedstocks in different production environments. Also important is that demand for biofuels has bid up feedstock prices substantially over the last two years and has thus resulted in an increase in the parity prices and/or an equally substantial reduction in profit margins for biofuel processors.

The present limitations in the economic production of biofuels from first generation feedstocks is due to the very high cost of the feedstock itself in the total cost of production. As shown in Figure 8, feedstocks account for the lion's share of total ethanol production costs. It follows that this is likely to remain a major constrain in expanding ethanol production from first generation feedstocks, even with increased efficiencies

[23] *World agriculture: towards 2030/50*, Interim report, FAO, Rome, 2006.

in conversion technologies. It also follows that as the demand of feedstocks for biofuel expand, their price increases which, it turn, reduces their competitiveness for that type of use.

Figure 7. Parity prices for various first generation feedstocks

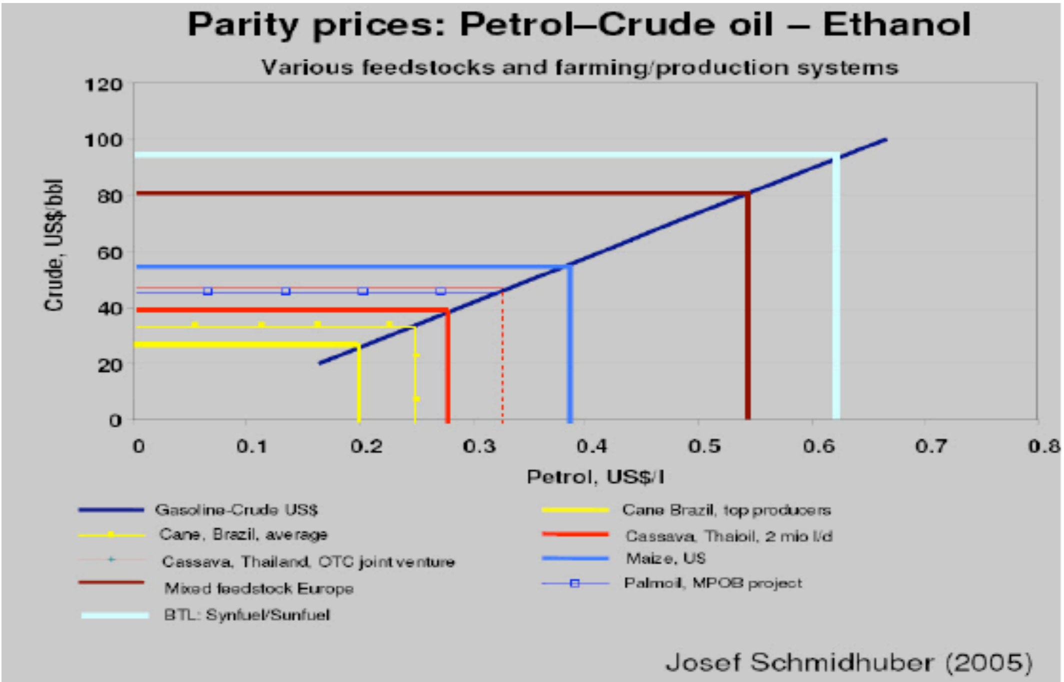
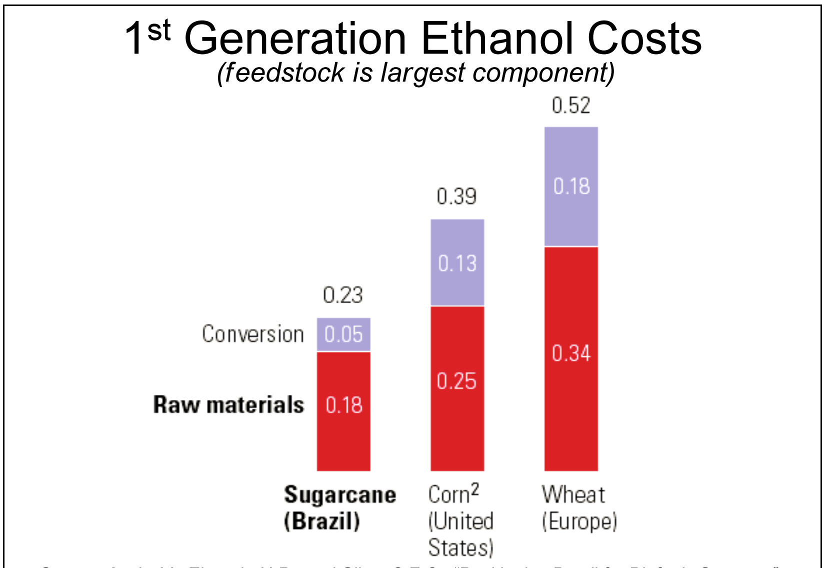


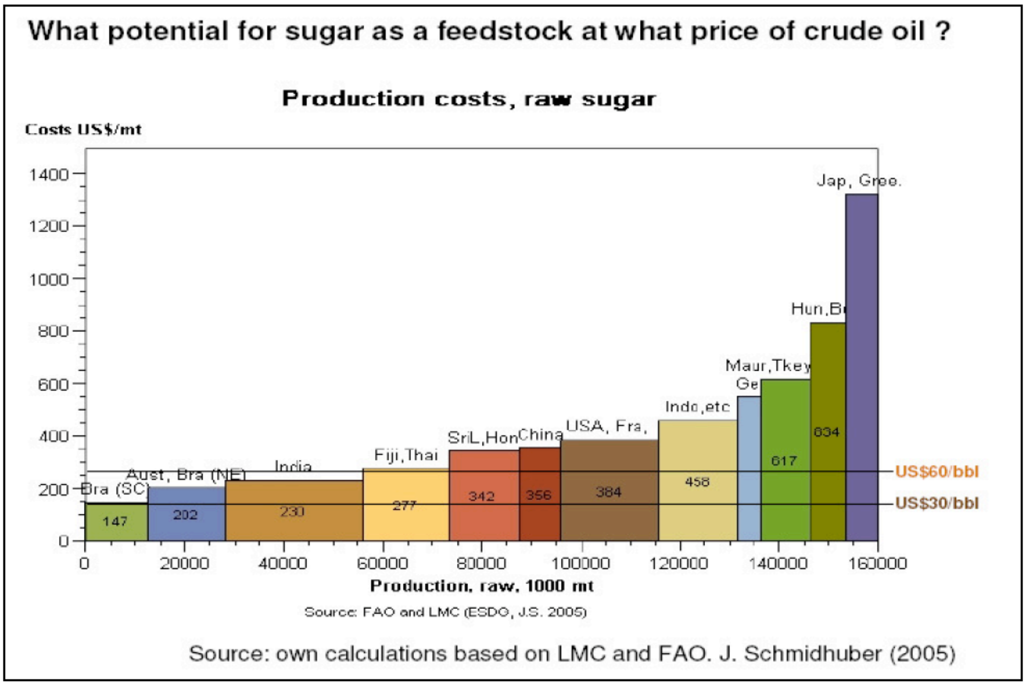
Figure 8. Share of feedstocks in the cost of ethanol production[24]



Source: Assis, V., Elstrodt, H-P., and Silva, C.F.C., "Positioning Brazil for Biofuels Success," *The McKinsey Quarterly* special edition on Shaping a New Agenda for Latin America, 2007.

[24] Larson (op. cit.)

Figure 9. Supply curve of ethanol based on sugar feedstock[25]



While sugar-based crops, and sugarcane in particular, are the most competitive feedstocks in ethanol production, its competitiveness varies widely from one country to another and also within the same country (e.g. South-Center vs. North-East Brazil). Figure 9 shows the estimated production costs of different sugar crops from different countries (a sort of a supply curve for ethanol based on sugar). At US$30/bbl, only a small part of sugar breaks even (some 12.5 million tons of South-Center Brazil out of a total global output of some 156 million tons in 2005). Even at US$60/bbl, only about 35 million additional tons would barely break even. Only at much higher energy prices would the rest of the sugar output begin to become competitive for ethanol production.

In summary, the extent to which biofuels can address the main objectives referred to above is debatable. As regards energy security, biofuels contribute a very small share of global energy needs presently. Even with more efficient use of biomass going beyond first generation feedstocks, the potential contribution of biofuels in meeting global energy needs in the future will remain low and in no way could replace conventional fossil fuels in any substantial degree or challenge the possibilities for developing other alternative sources of energy (solar, wind, etc).

Second, in terms of the energy balance also, the differences between various feedstocks are large and only sugarcane yields an unquestionably high output/input ratio.

Third, in terms of environmental concerns, the estimates of GHG emission reductions indicate that only some feedstocks have a substantial and positive CO2 balance, while for others the outcome is questionable. To the extent that environmental considerations weigh high in the global drive to reduce GHG emissions, it follows that efforts and resources should be devoted to the use of those feedstocks that have the highest impact. That would suggest that more attention should be given to ethanol production from sugarcane originating in tropical countries and less to grains from temperate zones.

Fourth, the objective of providing support to farmers, would critically depend on the price of energy and the willingness of governments to subsidize biofuel production. In the recent past there has been strong government support to biofuel programmes and this, together with the prevailing high energy prices has provided the incentive to invest heavily in the sector and to keep the prices of feedstocks much higher than they would have been. Thus, in the short term farmers supplying the feedstocks used in biofuel production

[25] Schmidhuber, Josef, "The nutrition and the energy transition of world agricultural markets", Plenary presentation at the German Association of Agricultural Economists (GEWISOLA), Göttingen, October 2005.

have been the clear beneficiaries of government programmes but it is to be seen whether the large government outlays can be sustained over the longer term. In addition, there are serious implications of such a policy for competitive ethanol producers elsewhere.

Finally, in terms of the competitiveness of producing ethanol on a large scale, only a small part of sugar-based crops are conceivably suitable for biofuel production at prevailing energy prices. Even at the prices we have experienced in the recent past, ethanol production barely breaks even in most of the countries with substantial ethanol production programmes and substantial further expansion would not be justifiable in economic terms. Moreover, the more a feedstock is demanded for energy use the higher its price and the less competitive biofuels become, given the very high share of feedstocks in the total production cost of biofuels.

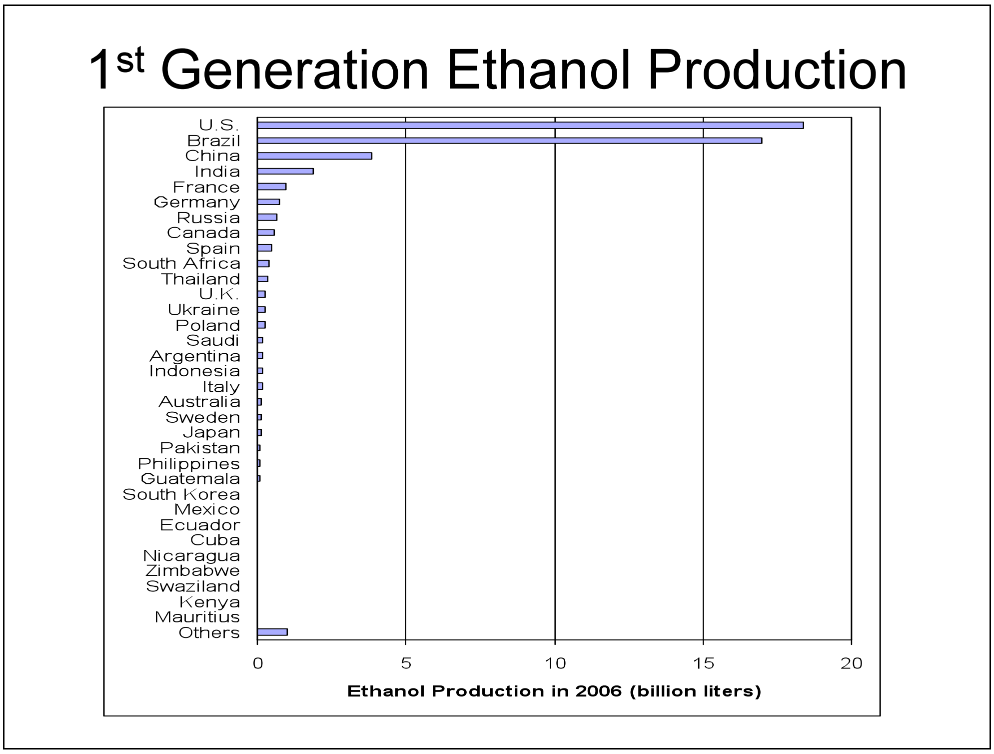
One further consideration is that at higher energy prices other sources of energy become competitive (solar, wind, etc.) some of which can make a much greater contribution than biofuels to the total global energy needs. Whether these alternative energy sources would pick up at a large scale and at what speed would depend to a large degree on private and public interest on such alternatives, including related R&D efforts and related government support compared to that provided to biofuels.

IV. ETHANOL SITUATION AND OUTLOOK

Production and utilization

Figure 10 ranks the ethanol producing countries in 2006. The US and Brazil are by far the leaders in the list, followed by China, India and EU countries[26]. Overall, the Americas account for three-quarters of global ethanol output (Figure 11). The same top producers of ethanol are also major world sugar producers, although only in Brazil among them the main feedstock used for ethanol production comes from sugar. Overall, globally sugar crops account for less than half (47%) of the ethanol produced with the rest coming from starchy crops (Figure 12). Ethanol is used in beverages, industrial purposes and as fuel, with the latter accounting for some 76% in 2007, projected to increase to nearly 90% by 2015 (Figure 13).

Figure 10. Global ethanol production in 2006[27]



[26] Swaziland produced some 130,000 hl of ethanol in 2006.
[27] Larson, op. cit.

Figure 11. World ethanol production by region[28]

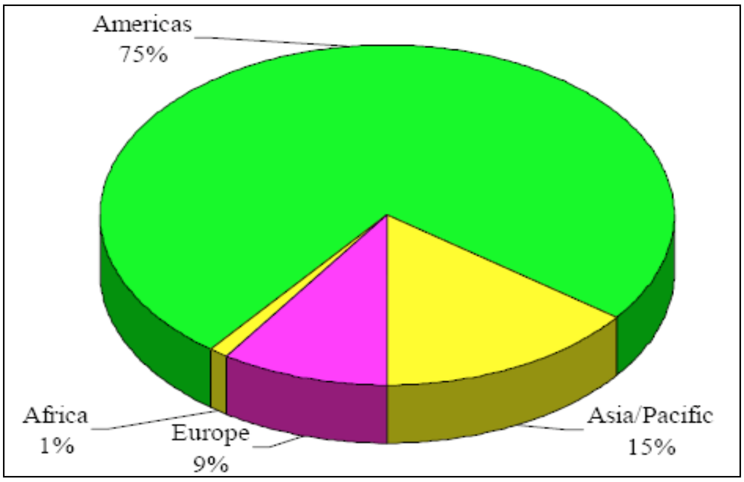


Figure 12. Feedstocks used in world fuel ethanol production[29]

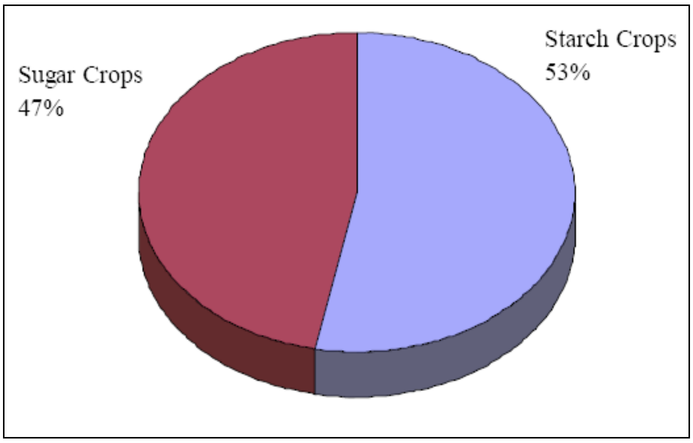
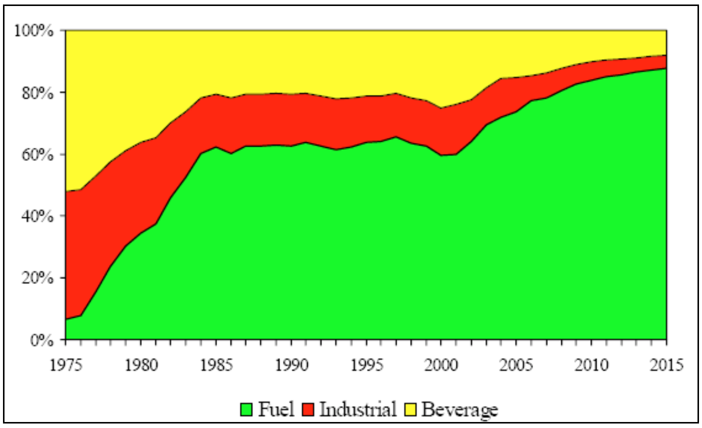


Figure 13. World ethanol use[30]



[28] F.O. Licht, op. cit.
[29] F.O. Licht, op. cit.
[30] F.O. Licht, op. cit.

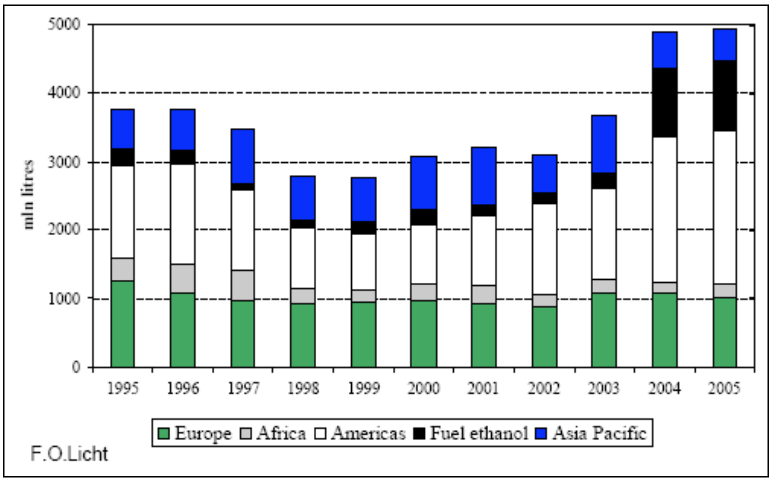
Trade

For a number of reasons, international trade in ethanol has traditionally been a small proportion of total production. Partly this is due to the fact that ethanol is widely produced in the world and local demand for beverages and industrial use is normally covered by local production. Another important factor is the tight government control on ethanol trade, including the high tariffs on most ethanol products. Yet another related factor is the heavy subsidization of ethanol production in a number of countries and regulations on its use, favouring domestic production to imported ethanol.

For many developing countries, access to developed countries is not a barrier since they benefit from preferential tariffs. ACP countries and LDCs enjoy duty-free access to the EU market and CBI countries, Mexico, and Colombia can export ethanol to the US market with a zero tariff. Other developing countries, however, such as Brazil, Thailand, and South Africa, are restricted by very high tariffs in the EU and in the US[31]. Despite these high duties, imports have occurred depending on the price levels of oil and ethanol, such as the situation experienced in the last two years.

In 2004 Brazil exported a large quantity of fuel ethanol to the US and EU. As a result, world trade volume increased close to 5 billion litres compared to around 3 billion litres up to that point, and the same high volume was also exported in 2005 (Figure 14). Together with the substantial increase in the volume traded, the world price of ethanol rose sharply, from around US$300/m3 in 2004 to US$400/m3 in 2005. The high crude oil prices and stronger international sugar prices contributed to this increase.

Figure 14. World ethanol trade (million hl)



Outlook

As production of biofuels has risen to the top of the policy agendas in many countries, it has also become a major driving force for food markets. The inextricable link of biofuels to agriculture and food in particular, implies that world markets for the related feedstocks (cereals and sugar), as well as oilseeds and palm oil for biodiesel, would be strongly influenced by developments in the energy sector. Thus, the outlook of the ethanol market and its effects on food markets are of particular interest.

The latest OECD/FAO Agricultural Outlook[32] focused on the effect on agricultural markets of developments in the biofuels sector. In particular, it incorporated into the projected outlook biofuel developments in several major producing countries, including the US, the EU, Canada, Brazil and China.

[31] In fact, these countries have the biggest potential for ethanol expansion and would benefit the most from higher market opening in developed countries. Many of them could have a real comparative advantage in biofuels production not only in terms of production cost, but also because sugarcane ethanol has a better energy and environmental balance than cereal and grain-based ethanol, as discussed above. These factors all argue for the expansion of biofuels exports from developing countries to developed countries and for a reduction of tariff and non-tariff barriers restricting such trade.

[32] *OECD/FAO Agricultural Outlook 2007-2016*, OECD/FAO, Paris/Rome 2007

Figure 15. The Top 10 Ethanol Exporters (million hl, 2005)

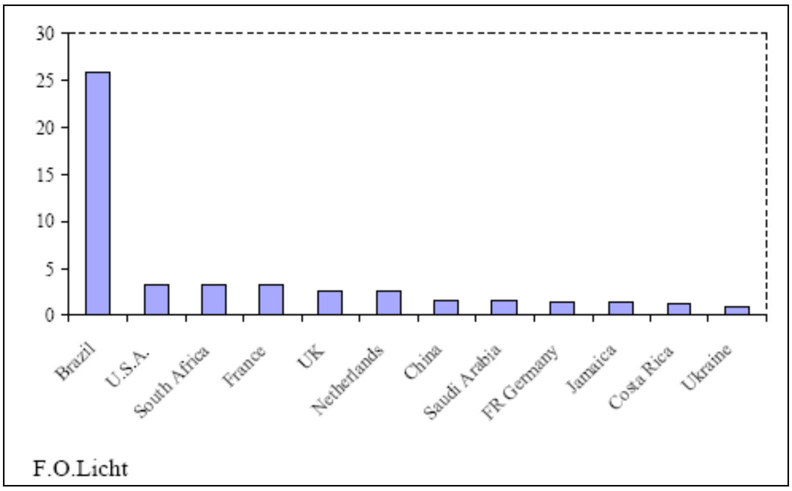
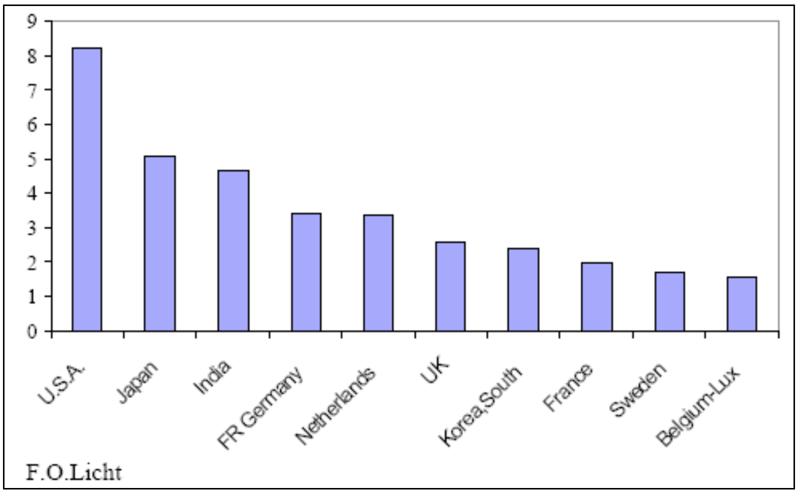


Figure 16. The Top 10 Ethanol Importers (million hl, 2005)

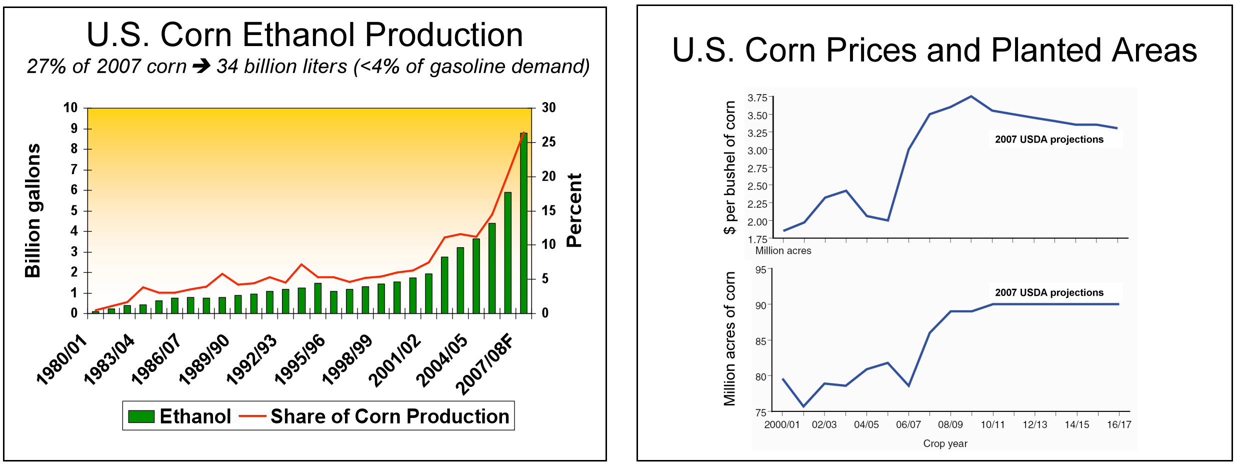


In the **US**, the 2002 Farm bill introduced, for the first time, specific measures to support the production of renewable energy based on agricultural raw materials. This program provides grants, loans, and loan guarantees for the development of renewable energy projects and energy efficiency improvements. In August 2005, the Energy Policy Act set a target of 28.4 billion liters consumption of renewable fuels by 2012, the so-called Renewable Fuels Standard (RFS). This would represent around 5% of gasoline consumption projected for the year 2012.

Partly as a result of these initiatives, ethanol fuel production and consumption in the US has risen dramatically in the past years. Between 2002 and 2006, production increased by an annual average of 23%, while consumption has grown by 27% per year. Ethanol blend in gasoline rose from 1.5% in 2002 to 3.8% in 2006, representing a consumption of 20.4 billion liters.

This rapid growth in ethanol production has had a strong impact on corn prices (the US ethanol industry is entirely based on corn). Presently, nearly a quarter of US corn production is dedicated to ethanol and is expected to rise while corn prices reached US$154 per ton in January 2007, a historic record (Figure 17), and are not expected to fall in the near future. Since the US exports approximately 65% of the corn traded in the international market, the upward trend in prices is also affecting other countries such as Mexico where the price of the “tortilla” has doubled in the last few months.

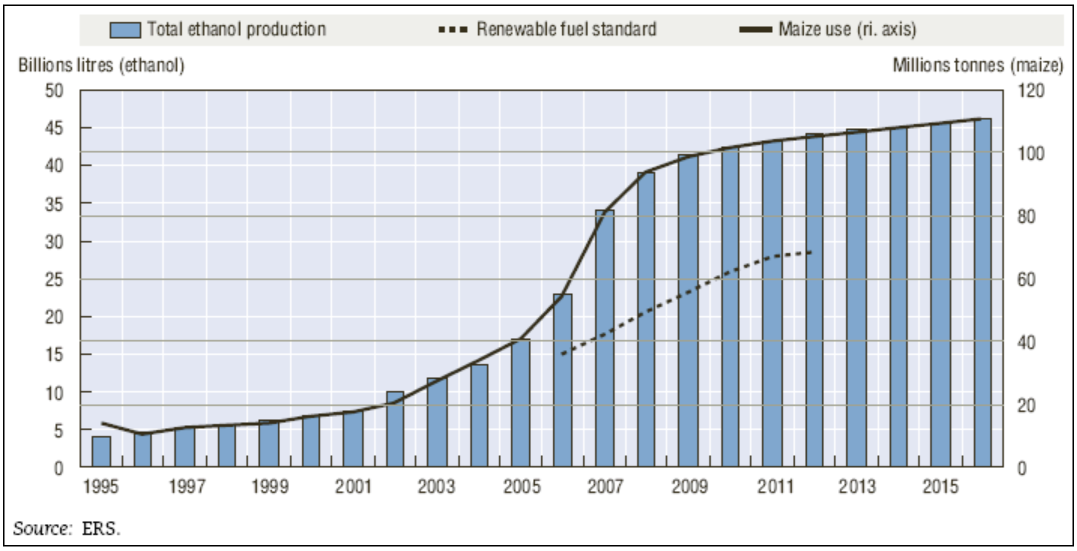
Figure 17 Corn use in US ethanol production and impact on corn prices[33]



Although MFN tariffs on ethanol in the US are low at 2.5%, there is a 0.14 US$/liter secondary tariff applied on imports (which represent an ad-valorem equivalent of 46%). The CBI countries enjoy preferential duty-free access to the US market, when ethanol is produced with at least 50% local feedstock (e.g., ethanol produced from sugarcane grown in the CBI beneficiary countries). If the local feedstock content is lower, limitations apply on the quantity of duty-free ethanol.

In the OECD/FAO projections, the US is assumed to substantially increase its ethanol production. Ethanol output is assumed to double between 2006 and 2016 (Figure 18). This expansion would exceed the requirements stated in the Renewable Fuel Standard (RFS) by far. In consequence, maize use for fuel production would increase from some 55 million tons, or one-fifth of maize production in 2006, to 110 million tons, or 32% of production at the end of the projection period.

Figure 18. Expansion of US ethanol production and corresponding use of maize



In the **EU**, biofuel production and use was historically for bio-diesel based on oilseeds, mostly rapeseed. Contrary to the situation prevailing in Brazil and in the US, where ethanol is produced from a single crop (sugarcane and maize, respectively), a large variety of feedstocks are used to produce ethanol in the EU. Cereals (wheat, maize, barley, and rye) account for the major part of the production, followed by sugar beet and wine. Sugar beet is the most efficient crop in terms of energy balance, yielding 7,250 liters of ethanol per hectare (compared to 3,125 for cereals).

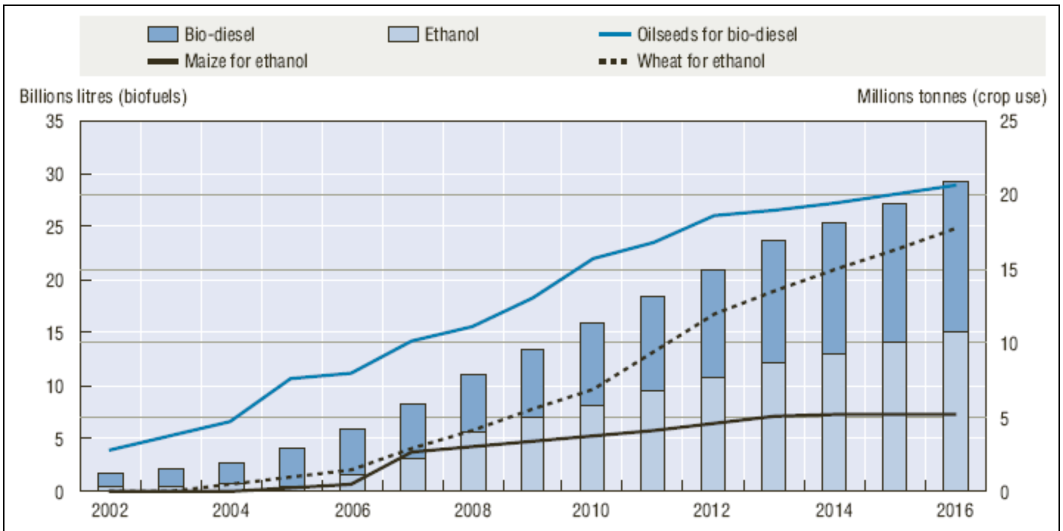
[33] Larson, op cit.

As in the case of the US, the production of biofuels in the EU is heavily protected and subsidized and government policies play a major role in providing incentives to production. The measures used include tax exemptions to support the biofuels industry and foster consumption and subsidies to agricultural producers supplying the feedstocks used in biofuel production.

The EU's domestic ethanol market is mainly protected by a specific tariff. MFN ethanol imports (non-denatured alcohol) face a specific tariff of €0.192/liter (63% ad-valorem equivalent). Very small quantities of denatured ethanol may also be imported for which the duty is €0.102/liter (39% ad-valorem equivalent). Several countries enjoy preferential access to the EU market, notably the ACPs and the LDCs.

In the OECD/FAO projections, it is assumed that increasingly ethanol, made mostly from wheat and maize, will become important on EU markets. Despite growth in total biofuel use by some 70% between 2006 and 2010, however, it is assumed that the share of biofuels in total transport fuel consumption will not exceed 3.3% in energy terms, rather than the 5.75% target envisaged by the EU Biofuels Directive. Further growth is, however, expected throughout the projection period (Figure 19). Use of wheat as feedstock is set to increase twelve-fold and to reach some 18 million tons by 2016. More moderate growth in the use of maize is envisaged.

Figure 19. Ethanol and bio-diesel use in the EU – based on wheat, rapeseed and imports

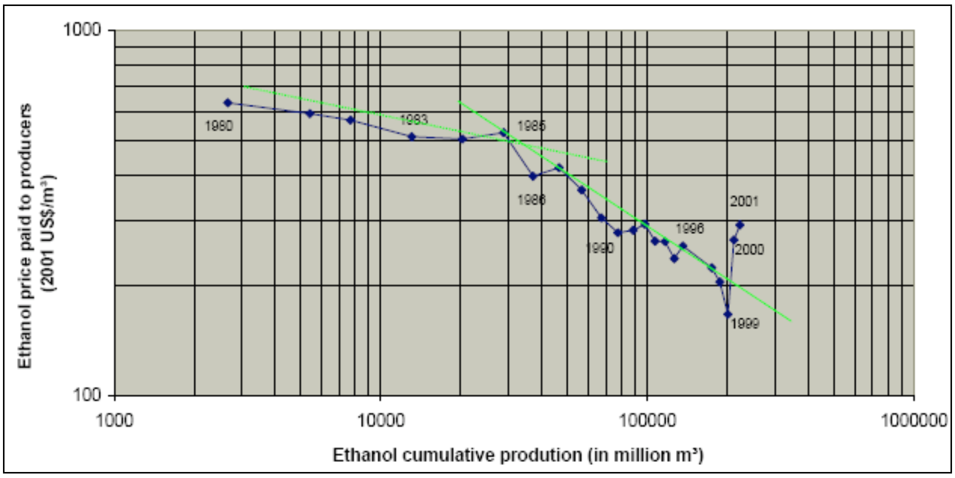


Note: Ethanol and bio-diesel data before 2006 refer to production, from 2006 to 2016 to consumption.
Source: EU Commission, OECD Secretariat.

Brazil is the world's leading sugar producer and exporter. Energy security, based on sugarcane, has been the driving force behind the Brazilian ethanol program, which began in the 1970s. The Brazilian sugar/ethanol market is probably the most developed and integrated in the world, on account of several factors[34]: (i) a high market penetration for cars that can run on ethanol or any blend of ethanol and petrol[35]; (ii) a country-wide system of petrol stations that offer ethanol; (iii) a growing share of sugar mills that can flexibly switch between sugar and ethanol production; (iv) a small but also rising share of specialized ethanol plants; (v) high-tech conversion and energy production systems, e.g. an integrated energy production system with growing share of combine heat power plants and electricity co-generation. There are 335 ethanol plants in the country and most are capable of producing either sugar or ethanol[36] using sugarcane as feedstock, with the shift between the two depending on relative market prices.

[34] Schmidhuber (2006), op. cit.
[35] The majority of the car sales in Brazil are Flex Fuel Vehicles (FFV) (80-90% of all sales of new vehicles).
[36] In recent years at a 50/50 ratio.

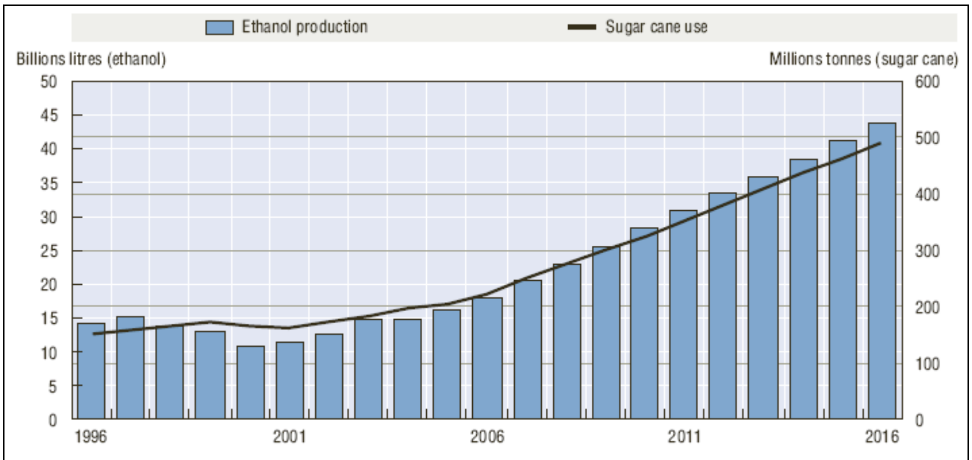
Figure 20. Ethanol learning curve in Brazil[37]



Despite subsidization in the earlier development periods, the cumulative knowledge over the last 30 years of cane-based ethanol production in Brazil has resulted in a sharp decline in production costs (Figure 20) and renders the industry profitable under current energy prices. For example, the integrated cane-based ethanol/electricity co-generation system in Brazil becomes a competitive energy provider at crude oil prices of about US$35/bbl. At this level, Brazilian sugar millers can produce ethanol cum electricity without subsidies.

In the OECD/FAO projections, it is assumed that ethanol production in Brazil would continue its growth to reach some 44 billion litres by 2016, 145% more than what was produced in 2006.

Figure 21. Continued growth in Brazil cane-based ethanol production



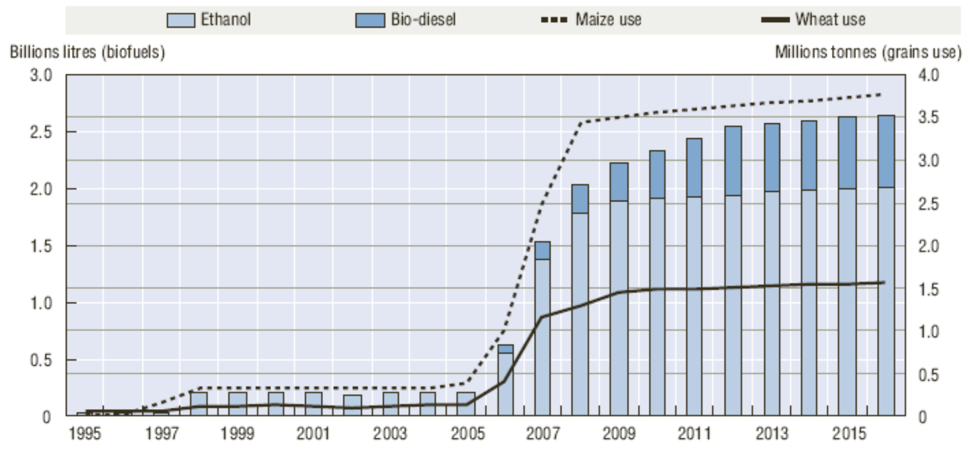
Source: OECD and FAO Secretariats.

Compared to both the US and the EU, biofuel production in **Canada** (a country with large fossil-based energy resources) is small in absolute terms. However, in 2006, the Canadian government mandated a 5% ethanol blend in gasoline by 2010 and a 2% bio-diesel blend in on-road diesel and heating-oil by 2012.

The OECD/FAO projections assume that these mandates are met, implying an increase in ethanol production to 1.9 billion litres in 2009, compared to 0.55 billion litres in 2006 (Figure 22). The assumed growth in ethanol production would consume significant quantities of maize and wheat.

[37] Goldemberg, José, Suani Teixeira Coelho, Plinio Mário Nastari and Oswaldo Lucon, "Ethanol learning curve - the Brazilian experience", Biomass and Bioenergy, Volume 26, Issue 3, March 2004, Pages 301-304.

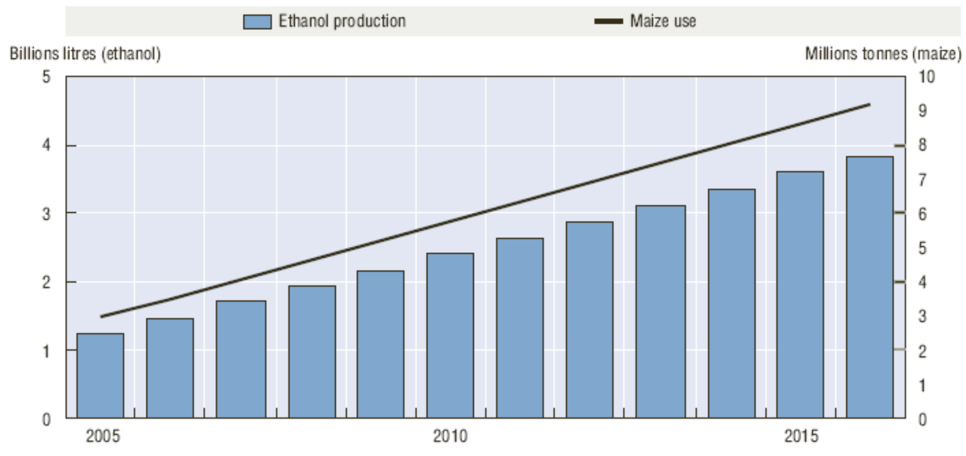
Figure 22. Canadian ethanol and bio-diesel production – based on cereal feedstocks



Source: AAFC.

Fuel ethanol production in **China** is assumed to grow steadily and to reach some 3.8 billion litres by 2016, up from 1.5 billion litres in 2006. Most of the fuel ethanol is expected to be based on maize (Figure 23).

Figure 23. Expanding Chinese ethanol industry using maize as feedstock

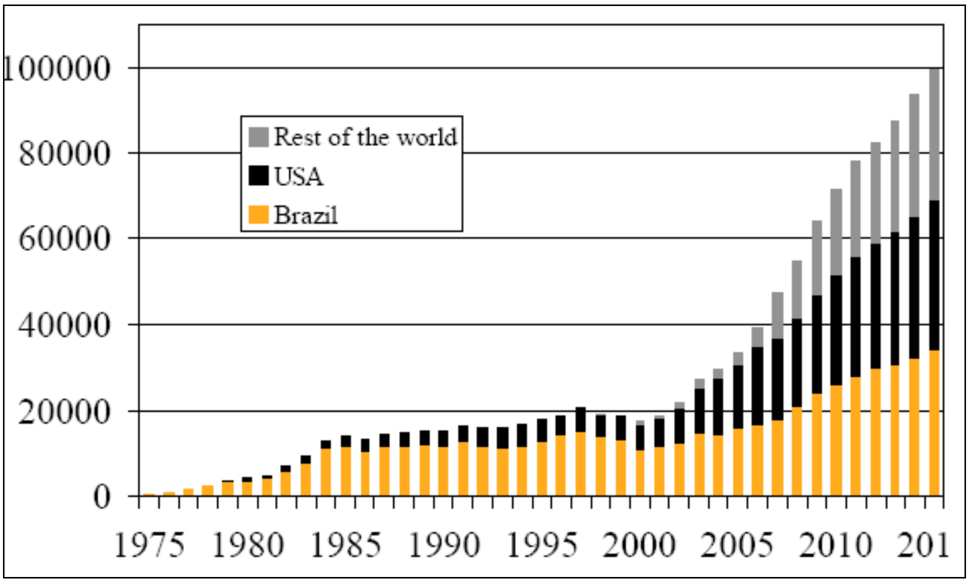


Source: ERS.

The OECD/FAO Outlook study concludes that the growing use of cereals, sugar, oilseeds and vegetable oils to satisfy the needs of a rapidly increasing biofuel industry, is one of the main drivers in food markets during the next decade. Over the outlook period, substantial amounts of maize in the US, wheat and maize in the EU[38] and other major cereal producing countries, and sugar in Brazil will be used for ethanol and bio-diesel production. This would underpin crop prices and also, indirectly through higher feed costs, the prices for livestock products as well. The implications for food prices over the next decade is of some concern to the net food importing developing countries and evokes the on-going debate on the "food *vs.* fuel" issue. The mechanism through which energy prices impact on food prices and the moderating factors in this relationship are examined in the next section of the paper.

[38] As well as substantial quantities of rapeseed for biodiesel production.

Figure 24. Projected world fuel ethanol production[39]



V. LINKAGES BETWEEN ENERGY PRICES AND FOOD PRICES

Energy prices drive commodity prices: floor and ceiling effects

Agricultural prices have always been affected by energy prices, as the cost of energy affects directly the cost of agricultural production through the prices of agricultural inputs, i.e. fertilizer, pesticides, diesel, etc. used in farming. Higher energy prices, translate into higher input prices and thus, other things being equal, reduced use of such inputs resulting in reduced output and hence higher output prices[40].

The demand for agricultural commodities as feedstocks for biofuel production has added to these "traditional" links between energy and agricultural commodity prices. The mechanism is basically through a direct price transmission effect from energy markets to agricultural markets. Thus, as prices for fossil fuels reach or exceed the energy equivalent of agricultural products (i.e. when higher energy prices make an agricultural product competitive for energy production), the energy market creates additional demand for such agricultural products. Given that demand from the energy sector is large, it sucks up the agricultural feedstock that becomes competitive in the energy market and thus raises feedstock prices. Effectively, through this mechanism, fossil fuel prices represent a floor price for agricultural commodities used as feedstocks into energy production.

This price effect is not unabated, however. The effect weakens as the extra demand for a particular agricultural feedstock drives its price up to a point where it becomes too expensive for biofuel production. Thus, in the long run, agricultural prices can not rise faster than energy prices. If they do, agricultural feedstocks price themselves out of the energy market. Thus, effectively, although the prices of the feedstocks used in biofuel would "chase" energy prices, the latter represent a ceiling price for the agricultural commodities in question[41]. The close relationship between sugar and energy prices is evident in Figure 25a.

These floor and ceiling prices apply not only to the crops directly used as feedstocks to energy production but also to other crops competing for resources on the supply side. Higher price for a given feedstock (e.g. sugar) attracts more resources in its production and, thus, less resources are devoted to competing crops. The supply of the later is reduced driving up their prices. Conversely, lower energy prices would amount to

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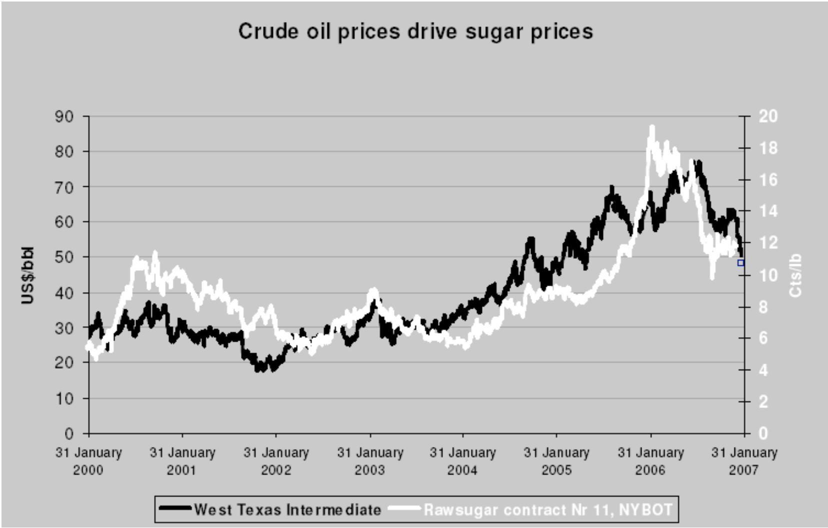
[39] F.O. Licht, op. cit.
[40] Some analytical issues on the new equilibrium price of grains following an exogenous change in the price of energy, can be found in Konandreas, Panos, "Interaction of Energy and Food Prices in Less Developed Countries: Comment", American Journal of Agricultural Economics, Vol. 58, 1976, pp. 592-594.
[41] For a more complete discussion on these points see Schmidhuber (2006), op. cit.

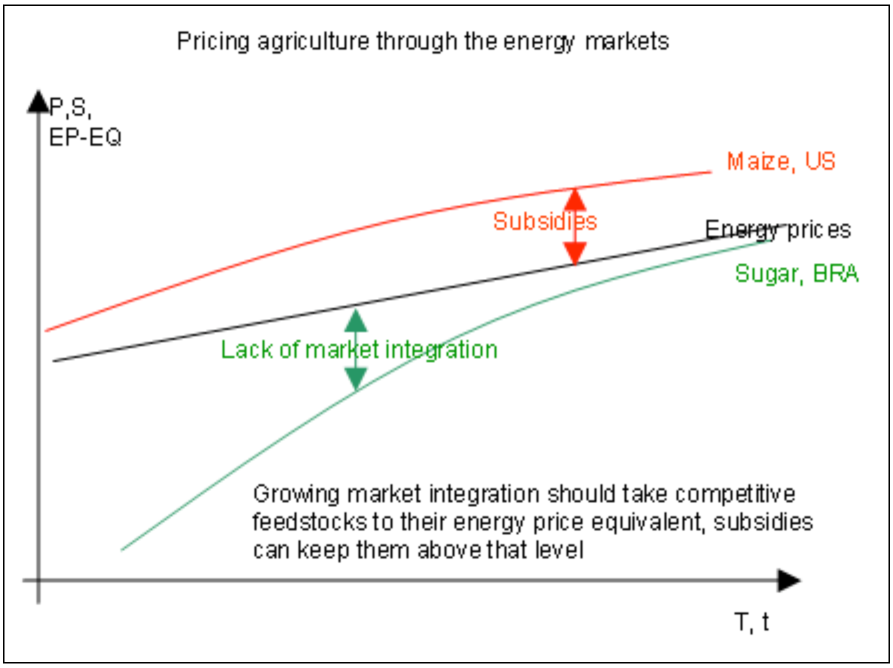
reduced demand for the agricultural commodity used in energy production, thus releasing resources devoted to its production for use by other competing commodities, eventually driving down their prices as well.

Figure 25a. Sugar prices track crude oil price above US$35/bbl



These market-based price dynamics and adjustments may not work well under situations of continued heavy subsidization or regulatory interventions in the biofuel sector. Figure 25b shows that energy prices determine and act as an effective ceiling to agricultural product prices. However, this ceiling price can be broken under certain conditions of government intervention in the biofuels sector. If rich countries intervene in the market through subsidies and border protection and/or impose certain regulations on how biofuels are to be produced and used (e.g. mandatory blending requirements) such that production/use of biofuels goes beyond economic considerations, this could push food prices higher than their energy price equivalent would suggest. Clearly, this would not only amount to an adverse effect on food security but also be akin to a new agricultural support system to the detriment of developing countries, as their producers may fail to benefit (they are excluded from developed countries' biofuel markets) and as their consumers still face higher food prices (maize)[42].

Figure 25b. Convergence and divergence of food and energy prices



[42] From a WTO and food security perspective, these are important points.

Simulated price effects

In general, prices for energy-rich crops (sugar, starch-rich crops or woody biomass) stand to benefit from the added energy demand, while those for protein-rich commodities and those for by-products of the bioenergy conversion process are likely to decline. Table 4 summarizes the impacts on international commodity prices for five different bioenergy scenarios. Price changes are long-term real terms changes relative to a scenario without agricultural feedstocks used for bioenergy.

Table 4. Differential price effects of different bioenergy scenarios

	An additional 10 million tonnes of ...				
	Sugar	Maize	Sugar and Maize	Soybeans and Maize	Sugar, Maize and Soybeans
Corresponding energy [biofuels]	0.195 EJ	0.087 EJ	0.282 EJ	0.167 EJ	0.349 EJ
Commodity	... used for biofuels would change international prices (percent) in the long-run by :				
Sugar	+9.8	+1.1	+11.3	+2.3	+13.8
Maize	+0.4	+2.8	+3.4	+4.0	+4.2
Vegetable oils	+0.3	+0.2	+0.2	+7.6	+7.8
Protein	+0.4	-1.2	-1.2	-8.1	-7.6
Wheat	+0.4	+0.6	+0.9	+1.8	+2.0
Rice	+0.5	+1.0	+1.2	+1.1	+1.4
Beef	+0.0	+0.2	+0.2	+0.4	+0.4
Poultry	+0.0	-0.4	-0.4	-2.1	-2.0

Source: @2030 simulation results

The results from model-based simulations suggest that when an additional 10 million tons of sugar is used for ethanol production, its own effect on sugar prices would be substantial, in the order of 10% or more, depending on the scenario. The own price effects of using the same quantity of other feedstocks in biofuel production are much less, in the order of 2-4% or less.

The result also suggest that if biofuels are produced from feedstocks with high protein contents (oilseeds, notably soybeans, but also cereals), the downward pressure on protein prices is likely to be substantial. As expected, the extent of the downward pressure strongly depends on the protein content of the feedstock. It is likely to be particularly pronounced in the case of biodiesel production from soybeans, where, for every litre of biodiesel, 4 kg of soybean meal will have to be absorbed by the market. The depressing effect on protein prices is substantial (8%) when the additional soybean used in biodiesel production is combined with the same amount of maize for ethanol production. Also derived products which require large quantities of protein feed such as poultry meat would experience a more moderate downward pressure on prices (2%).

VI. POSSIBLE IMPLICATIONS FOR SWAZILAND

Swaziland is largely a rural subsistence economy and maize is virtually the sole staple for the majority of the population. It is grown by the vast majority of rural households and accounts for approximately 86% of the entire land cropped on communal Swazi Nation Land (SNL). Sugarcane, the other major crop, dominates agricultural production on the roughly 31% of the total geographic area of Swaziland held by individuals and companies as Title Deed Land (TDL) and also on an increasing part of SNL. The agricultural sector contributes to the livelihoods of the majority of the population and provides raw materials for the agro-industry (mainly sugar, citrus and wood pulp). The contribution of agriculture to GDP is estimated at about 11% (2001-06), compared to 50% from industry and 34% from the service sector. Coal is the major mineral resource. The main merchandise exports are sugar and sugar derivatives (largely under preferential terms), consumer goods and pulpwood. Imports include mainly capital and intermediate goods, manufactured goods, machinery and transport equipment, agricultural and farming goods, foodstuffs and energy. South Africa is the main trading partner from which it receives over 80% of its imports and to which it sends 74% of its exports.

Swaziland is classified as a lower middle-income country with a per capita income of US$2,280 in 2005. Yet income distribution is extremely unequal, with the wealthiest 20% of the population accounting for more than half of total consumption and there is an ever-widening gap between urban and rural areas[43]. About 43% of the population live in extreme poverty and about 76% of the poor live in rural areas. Such high poverty levels mean that much of the population is vulnerable to food insecurity. In the last few years between one fifth and one quarter of the country's population have depended on food assistance[44].

Food inflation soared to an annual 14.6% in 2006 from an average of 9.1% in 2005. With rising oil and food prices coupled with weakening exchange rates, further increases are expected in 2007. For instance, the price of maize has risen from E1 250 (US$169) per ton in January to E2 300 in April 2007, an almost 90% increase.

The total population was estimated at 930,000 in the 1997 census (growing at an annual rate of 2.9%) and estimated at about 1.2 million in 2007[45]. However, in view of the HIV/AIDS pandemic (infection rate at 56% in the 25-29 age group is the highest in the world), the population growth rate has fallen rapidly and by 2010 is projected to be negative (-0.4%). Average life expectancy has fallen from 56 in 1997 to 41 in 2004 and is projected to decline further until 2010, when it would reach its lowest level at 31 years.

In addition to its humanitarian and social consequences, HIV/AIDS costs the country severely in economic terms. For instance, a study of subsistence agriculture in the country found that, due to HIV/AIDS related sickness and deaths, 38.5% of households suffered reduction in area under cultivation, 47% decline in crop yields, 42% change in cropping pattern, 31% diversion of labour to care for the sick, 22% increase in health costs and 39% loss of regular remittances[46].

Growing food import dependency and expansion of sugar production

Among the two principal crops, sugarcane production has shown a slow but steady increase in recent years, whereas the area planted to maize has shown a decline (Figure 26). This has been partly the result of government policy encouraging sugarcane production on irrigated land in order to increase export earnings while the production of maize remains mostly on non-irrigated land. In line with the increase in area under

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[43] According to the *Human Development Report 2005,* produced by the UN Development Programme (UNDP), the Gini coefficient measure of income inequality for Swaziland is 60.9, one of the highest in the world. The country's ranking in the UNDP's human development index in 2006 is 146th of 177 countries.

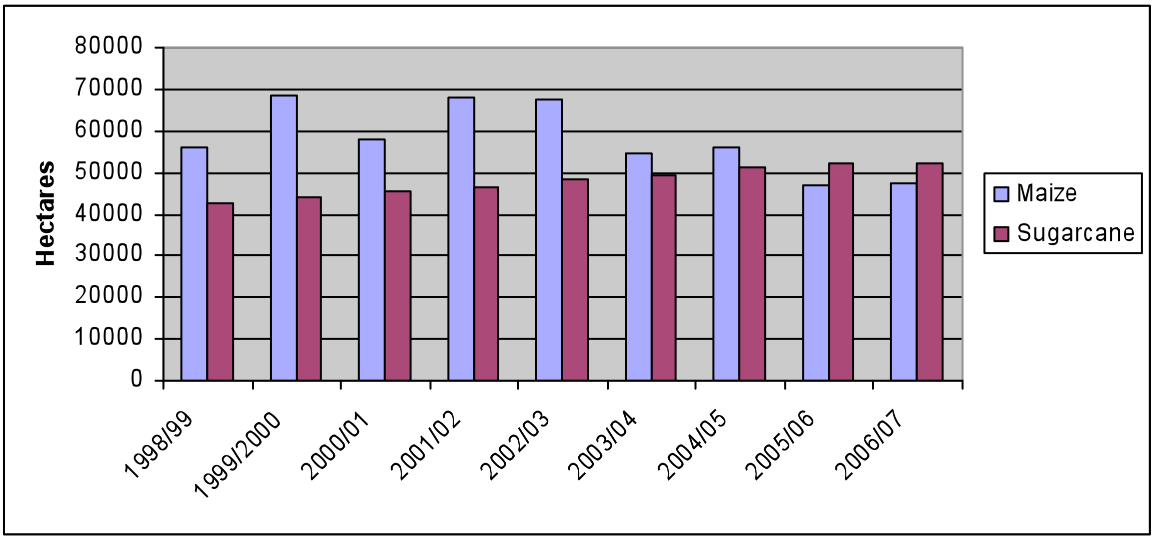
[44] FAO/WFP Crop and Food Supply Assessment Mission to Swaziland, Special Report, 23 May 2007.

[45] Based on reports from the National Early Warning Unit, Ministry of Agriculture and Cooperatives.

[46] *The Impact of HIV/AIDS on Agriculture and the Private Sector in Swazilan*d, , Ministry of Agriculture and Co-operatives, the Federation of Swaziland Employers and UNAIDS, 2003, Jubilee Printers, Matsapha Swaziland.

sugarcane[47], production increased from about 3.9 million tons in the late 1990s to 5.2 million tons in 2005/06, while that of maize declined by nearly half during the corresponding period.

Figure 26. Area planted to maize and sugarcane in Swaziland[48]



The country depends on food imports for a substantial share of its food needs. In recent years, over 60% of cereals consumed in the country were imported compared to 40% in the late 1990s (Table 5). Normally, over 60% of the imported cereals is maize, some 30% wheat and the remaining 10% rice. Commercial food imports appear to have been responsive to the fluctuations and general downward trend in national production. However, the impact of erratic weather in recent years combined with declining off-farm incomes, remittances and the impact of HIV/AIDS have rendered large number of households dependent on food assistance and growing share of their needs are met by food aid. The current year's maize crop is assessed to be one of the worst harvests ever (with 2007 maize output over 60% below 2006 level). In view of this, the food security situation in Swaziland during the 2007/08 marketing season is of particular concern[49].

Table 5. Growing dependence on food imports in Swaziland

	Average 1996-2000	Average 2001-2005
	1000 tons	1000 tons
Production	123.5	65.1
Imports	75.6	123.9
Commercial Imports	72.4	106.6
Food Aid	3.2	13.8
Import dependency (%)	**40.4**	**63.1**

In view of the declining production of maize, the food import bill of the country absorbs an increasing share of export earnings and it stands at some 20% of total merchandize imports in recent years. However, partly

47 From 37,384 ha in 1992/93 to 52,196 ha in 2005/06. It must be noted, however, that the increase in area under sugarcane has coincided with the increase in the entry of smallholder sugarcane farmers in the industry. Presently, the industry has about 500 small-scale sugarcane growers, which were virtually non-existent in the early 1990s.
48 FAO/WFP Crop and Food Supply Assessment Mission to Swaziland, Special Report, 23 May 2007.
49 *Crop Prospects and Food Situation*, No. 4, FAO, July 2007.

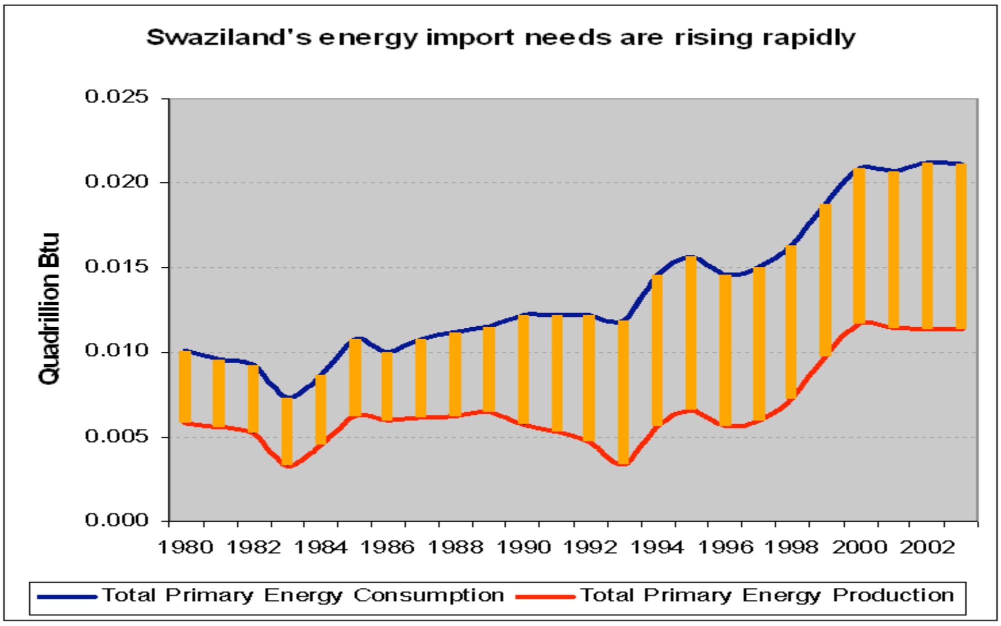
on account of sugar[50], about 30% of which is sold under preferential terms to the lucrative EU market, Swaziland's agricultural trade balance is positive, although the aggregate balance for all merchandise trade has been consistently negative.

The challenges and possible responses

The combination of both domestic and international developments discussed above point to negative outcomes for Swaziland in the short to medium term. The interrelated economic issues of concern include dependency on one main export commodity (sugar and related products) subject to eroding preferential terms, an increasing dependence on increasingly expensive imported supplies to meet basic food needs, and also the country's dependence on the precarious world energy market for covering its growing energy requirements. These issues, combined with the very high incidence of HIV/AIDS, which however goes well beyond the scope of this paper, present a formidable challenge to economic and social policy-makers in Swaziland.

Reduced foreign exchange earnings in view of the gradual erosion of sugar preferences in the EU market has been of concern to Swaziland as it is in a number of other ACP countries which have enjoyed access to the lucrative EU market, where their quota exports fetched a price often twice the world price. The EC proposals for sugar-sector reform tabled in June 2005 seek to bring the EU sugar regime into line with CAP reform, by shifting from a system of price support to a system of direct aid payments to EU farmers[51]. At the same time, an "Action Plan on accompanying measures for sugar-protocol countries affected by the reform of the EU sugar regime", addressed the issue of restructuring support to ACP sugar exporters. These measures aimed "to help sugar-protocol countries to adjust to the changing market conditions by enhancing competitiveness of their sugar sectors, by diversifying into other economic activities or by addressing broader social, economic and/or environmental impacts of these changes"[52].

Figure 27. Increasing energy imports: a case for import substitution?



[50] In addition to sugar, other important agricultural export products are citrus fruit, canned fruit and wood pulp.
[51] "EU sugar-sector reform: European Commission proposals and member-state and ACP responses", EC, June 2005.
[52] In the June 2005 press release the EC also noted that in assisting the ACP in adjusting to change, the EC 'proposes to cover a broad range of social, economic and environmental actions' and that an initial budget of euros 40 million had been earmarked for 2006 and that further long-term assistance will be secured for the period 2007-2013. The EC also announced its intention to 'start implementing the assistance scheme as soon as 2006, as early investments in these countries will maximise their chances of successful adjustment'.

The increased demand for sugar during the last two years and the projected further increase in its use for ethanol production would strengthen world sugar prices somewhat, as discussed above, but not enough to balance out preference erosion losses. The likely boost in world sugar prices, of say 10-15% compared to where they would have been in the absence of ethanol production, is marginal in comparison to the ultimate huge reduction in preference rents[53]. However, this strengthening of world sugar prices would compensate somewhat the preference erosion effect. Thus, although normally sugar sold to the world market fetched about half of the EU preferential price, the drop in revenues is likely to be less than that, roughly in the order of 25-30%[54].

The role that sugarcane played (in terms of foreign exchange earnings) in affording Swaziland the capacity to import food is therefore eroding. This would imply that while a policy of promoting sugarcane at the expense of maize may have been based on good premises in the past, these would not hold true in the future. The revenues from the sugar sector are likely to decline while at the same time the cost of importing food is likely to increase. Hence the rationale of a strategic policy based on sugarcane would need to be revisited and, in particular, the neglect of maize production (and the associated rapid increase in import dependence) would need to be redressed.

What is also important during this period of adjustment is to make sure that sugarcane farmers, especially the many smallholders who entered the sugar market during the period of expansion in recent years, are not disproportionally affected from the expected overall reduction of revenues from the sugar sector.

In addition to this internal restructuring of production, other more innovative ideas for diversification in the sugarcane sector itself are also possible and would need careful consideration. These include, inter alia, prospects of bilateral or multilateral aid transfers for climate change mitigation, an idea that is generating significant interest in biofuel production in many developing countries, or more precisely, Annex 2 countries of the Kyoto Protocol (see Annex). Annex 2 countries (mostly developing) do not currently have binding GHG reduction targets under the Protocol but, under the Clean Development Mechanism (CDM), one of the three mechanisms that should help reduce carbon emissions, they can sell *certified emission rights (CERs)* to Annex 1 countries of the Protocol (mostly developed) who obtain in turn carbon credits for their own emission reduction commitments.

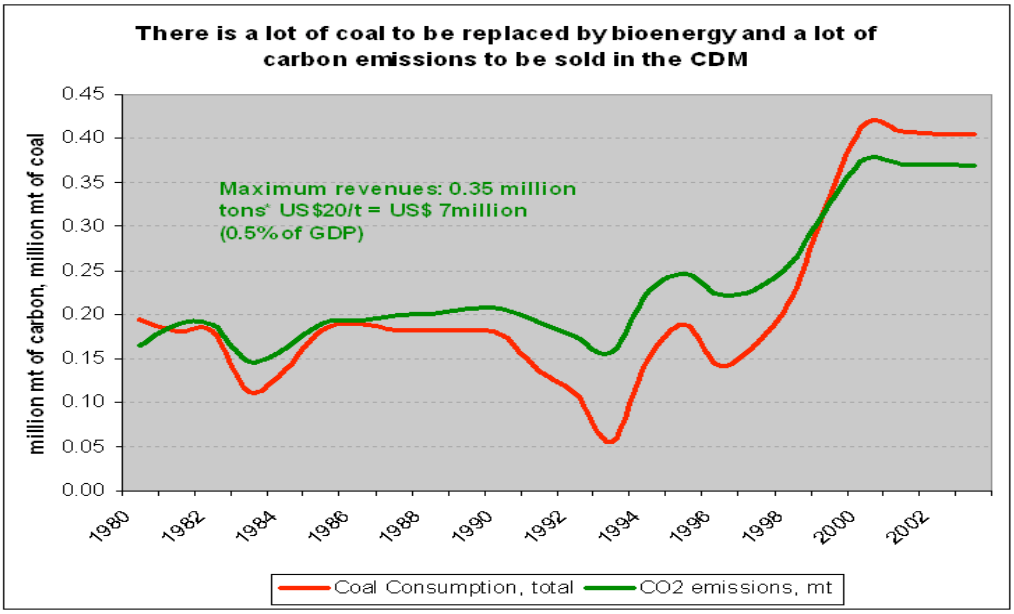
The rationale of the CDM is that by and large, as discussed in section III, the overall energy use efficiency in developing countries is much lower than in developed countries, which allows the former to accomplish emission reductions at much lower costs. At the same time, investments in improved energy efficiency or carbon sequestration in developing countries bring about multiple benefits for them. Such investments are important carriers of know-how, afford recipients with otherwise scarce capital and typically reduce not only GHG emissions but improve overall environmental performance. For instance, investment in landfill projects do not only reduce GHG emissions, but can also help improve overall air and water quality in a recipient country. Likewise, investments in an afforestation project will not only add to the country's carbon sequestration capacity, but also enhance local water quality and domestic biodiversity. Or, and that could be crucial for a country like Swaziland, investments in its domestic cane-based biofuel industry could improve the overall processing efficiency of the sugar industry, but also establish new sources of domestic energy production.

Specifically, the benefits of a CDM project in Swaziland's cane industry could include: (i) foreign exchange inflows from selling CERs to Annex 1 countries which would help reduce the country's current account deficit and/or provide the proceeds to increase food imports; (ii) modernization of its sugar industry to accomplish higher processing efficiency; (iii) creation of a new energy source through electricity co-generation of bagasse processing in the sugar mills; in fact, so far, only the electricity co-generation part would allow to earn CERs within the CDM; (iv) a revitalization of its agricultural sector and thus new income prospects of an otherwise shrinking agricultural sector. These benefits notwithstanding, they should

[53] A much greater boost in sugar prices would have been realized from, as the world sugar market is one of the most distorted. Model simulations have assessed that complete trade liberalization, which would have dramatically reduced sugar production in the subsidizing high-cost countries, would raise the world price of sugar by about 30–40% (in "The Potential for Biofuels for Transport in Developing Countries." Report 312/05, ESMAP, World Bank, October 2007.
[54] This is a very rough assessment based on the average proportions of sugar sold to the EU (some 170,000 tons out of a total output of 540,000 tons) and to the world market, respectively.

not necessarily imply a further expansion of sugarcane production. Such an expansion would need a careful analysis as it could create additional risks and some outright pitfalls. For instance, cane production is very water-intensive and an expansion of the country's cane acreage could aggravate existing water shortages. Also, higher proceeds from ethanol or electricity production may not necessarily benefit the most needy. , In fact more land for cane production is likely to increase land competition, will bid up prices for food and may even harm the landless rural poor or large parts of the rapidly growing urban population.

Figure 28. Swaziland's potential revenue from selling CO2 emission rights



The potential in the EU market for ethanol exports could be of particular interest to Swaziland. As mentioned above, the EU is committed to provide financial and technical support to ACP countries, members of the Sugar protocol, in compensation for the EU 2006 sugar reform. Part of this aid could be dedicated to the establishment of ethanol production, and part of that future ethanol production could be exported to the EU market[55]. In fact, recently, the EU announced more concrete plans to support biofuel production in developing countries[56]. The EC Development Commissioner said that the EU would allocate part of a 220 million euro ($300 million) foreign aid budget to offer countries investment and technical skills "so they can jump on the biofuel bandwagon". He added that the EU is currently studying how sugar producers from ACP countries could turn to ethanol production while other regions could grow oilseed crops.

At the same time the EC Trade Commissioner in a biofuels conference organized by the EC in Brussels, stressed that it is unlikely the EU will be able to hit the target of replacing 10% of transport fuel with biofuels by 2020 without stepping up foreign trade. "We should certainly not contemplate favouring EU production of biofuels with a weak carbon performance if we can import cheaper, cleaner biofuels," he said, and he observed that "Many developing countries have spare agricultural capacity and a genuine comparative advantage in production."[57]

Preferential access to the EU market may not be needed, depending on world energy market developments, but it could be of assistance to a small supplier like Swaziland with limited power in the market. Beyond aiming at the export market, however, there should be import substitution opportunities in the energy sector for a landlocked country like Swaziland. Being a net importer of fossil fuels (at high delivered costs) and electricity, Swaziland may be able to enhance its energy security through the substitution of transport fuels by domestically produced ethanol and also meet a greater share of its electricity needs.

[55] Some EU countries (Sweden, for example) are already importing ethanol from competitive countries instead of buying expensive biofuels produced in EU neighboring countries.
[56] "EU aid to help developing countries jump on biofuel bandwagon", *Biofuels News*, July 10, 2007 http://news.independent.co.uk/europe/article2742787.ece
[57] *The Public Ledger, World Commodity Weekly*, No. 72533, July 9, 2007.

In this context, the experience of Brazil deserves careful study. Brazil's current position in the ethanol market draws on some 30 years of experience in the sector from improving sugarcane varieties to developing efficient conversion technology. Also Brazil benefits from economies of scale. However, certain aspects of Brazil's ethanol industry are easily transferable to other countries. This includes engineering design and plant construction and the know-how to run an integrated sugar/ethanol/electricity production process. In addition, attention should be paid to entrepreneurial and managerial skills, and a cadre of technical people capable of running and maintaining production plants.

Beyond the technical considerations, the role of the government in supporting adjustment in the industry (beyond its normal regulatory role) is essential, as has been the case in all countries that have moved into biofuel production. It is conceivable that such government support may not be needed in the longer term, as prices above $50 per barrel are predicted by a number of analysts over the next few years. With world oil prices remaining high for a prolonged period of time, biofuel programmes have a better chance of becoming financially viable without sustained government support. However, the less-likely downside price risk is also of consideration, posing a challenge to the financial viability of biofuel production without government support[58].

VII. CONCLUDING REMARKS

Biofuels have a role to play in the global efforts to meet energy needs, mitigate environmental effects and climate change, and in promoting development. Some of the claims in terms of the positive aspects of biofuels have been overstated as have been some of the claims for their negative effects. As always, the truth is to be found somewhere in between taking into consideration the specifics: what feedstocks are used, where they are produced, the socioeconomic environment under which they are produced, how they are processed, the conditions under which they are traded, etc. The bottom line is that not all is good and not all is bad and the role of public policy is to restraint the former and encourage the latter.

While first generation biofuels do not have the potential (in terms of the quantities needed) to meet a large part of growing global energy needs, the extent to which they are used in energy production should be rationalized on the basis of global criteria and not on short-sighted domestic agricultural policy considerations. From this perspective, sugarcane has the highest potential. On all accounts (energy balance, environmental balance and cost of production) it surpasses other feedstocks used in ethanol production by far.

Bioenergy demand has had – and will continue to have – a direct effect on agricultural markets and prices. Rising prices for fossil energy have made a growing number of agricultural commodities competitive feedstocks for the energy market. The extra demand has resulted in a global increase in agricultural commodity prices and the creation of a *floor price effect* for competitive feedstocks. The potential demand from the overall energy market is so large that it could result in a *change in the overall paradigm* of rapidly rising supply, increasingly saturated demand and falling real prices that has governed international agricultural markets over the last 40 years.

Higher real prices in agriculture will have numerous effects on rural areas, rural industries and food security. They create opportunities but also new challenges. Higher real prices can help revitalise rural areas and help reduce rural poverty. The combination of higher prices and more marketable produce will raise overall revenues for agricultural households. In tandem, rural, non-agricultural households could benefit from new employment opportunities and higher wages and thus higher incomes. The positive income effect should be particularly pronounced where bioenergy production and processing is labour-intensive and access to land is relatively equitable. Overall, the effect could be a global *renaissance of agriculture* and a revitalisation of rural areas.

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[58] Kojima, M. and T. Johnson (op. cit.) enumerate several important considerations in assessing the likelihood of commercial viability of biofuel programmes over the long run.

The growing dependence of agricultural prices on energy prices also means that there will be an endogenous cap on food price increases. In order to remain competitive for the energy market, agricultural feedstock prices cannot rise faster than energy prices in order to remain competitive as a source of energy. This creates an implicit *ceiling price effect*, which is given by the energy equivalent of an agricultural feedstock. The ceiling price effect is crucial for understanding that agricultural prices and markets will not continue the recent boom sparked by the spike in oil prices but also to understand that concerns about a looming global *neo-Malthusian scenario are unwarranted*[59]. Only if energy prices continue to rise will agricultural prices follow. With rising energy prices and a growing degree of market integration between energy and agricultural feedstock markets, both the levels and variability of agricultural commodities will increasingly be determined by those of energy prices.

These global changes in agricultural commodity markets will not leave small countries unaffected, not even if they are relatively insulated such as land-locked Swaziland. For Swaziland, these changes in the international market environment come at a time where the country in general and its agricultural sector in particular are faced with formidable challenges. These challenges include: the high humanitarian and economic costs of HIV/AIDS, the loss of preferential access to one of its key export markets (EU), complete dependence on energy imports, high energy prices and a rising current account deficit.

High energy prices are expected to remain a feature for the coming decades; this creates opportunities and challenges for Swaziland in general and its agricultural sector in particular. If well managed, bioenergy could reduce the country's dependency on imported energy, help reduce its overall foreign exchange deficit, and revitalize its rural economy in general and its agricultural sector in particular.

To minimize the problems and harness the benefits, policies both at the national and international level can play an important role. Some assistance could be provided by fully harnessing new policy options such as the CDM, international carbon funds or bilateral schemes such as the EU's EPA. These options could help manage Swaziland's difficult economic and agricultural transition, re-capitalize and modernize the country's sugar industry, promote FDI and know-how inflows and help mitigate local and even global environmental problems. Bioenergy could also help diversify its agricultural sector and facilitate the transition in the ACP reform process of the EU.

At the national level, attention should be paid to minimizing possible negative side effects of an expansion of bioenergy production, such as water scarcity; land competition for food production and rising food prices; massive "capital for labour substitution" and thus rural unemployment; and no "trickle down effect" for the rural poor. Domestic measures could help the landless rural poor to cope with higher food prices or help them find employment in the bioenergy/sugar industry. In this context, other forms of rural activities should be explored, including other forms of bioenergy crops that are more labour intensive and less water intensive. Jathropha could be one of the options, particularly where water is scarce and where labour is cheap.

At the multilateral level, various impediments to investment need to be addressed recognizing that efficient and internationally competitive bioenergy production is a know-how and capital-intensive process. To facilitate such a process, ways and means need to be explored to provide foreign capital (ODA, FDI, etc.) and/or to pool domestic capital sources (e.g. in biofuel co-operatives); foreign assistance could also be provided to facilitate a better understanding of the options and international mechanisms available to obtain access to schemes such as the CDM, the carbon funds of the IFIs, or of the private sector. Such technical assistance is well known and established in "Aid for Trade" and could be expanded to provide a better understanding of and better access to these new environmental schemes.

Finally, international policy action would also include better access to the burgeoning but largely protected biofuel markets of many developed countries. Providing tariff-free access to these markets and removing other regulatory mechanisms impeding imports is fundamental to a win-win outcome for all concerned.

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[59] The predictions of a massive dooms day scenario caused by an increase of use of agricultural commodities for biofuel are numerous and massive. For instance, BBC International quotes the Cuban Fidel Castro of claiming that the US ethanol programme alone will cause 3 billion deaths from hunger, i.e. half the world's population. http://news.bbc.co.uk/2/hi/americas/6505881.stm

Annex Table 1. Trends in world ethanol production

World Ethanol Production (1000 hl)							
	2006	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
Austria	108	70	72	81	87	91	83
Denmark	205	210	218	220	201	209	189
France	9,500	9,100	8,300	8,166	8,440	8,124	8,124
Germany	5,500	3,500	2,300	2,800	2,750	2,950	2,850
Hungary	650	580	538	466	429	425	433
Italy	1,700	1,500	1,500	1,490	2,000	2,070	2,056
Poland	2,300	2,200	2,000	1,700	1,650	1,580	1,600
Spain	4,750	3,762	3,344	2,923	2,575	2,250	1,450
Sweden	1,150	1,100	1,050	1,000	970	920	174
U.K.	2,800	2,900	3,500	4,100	4,000	4,300	4,350
Other EU	2,720	2,251	2,132	2,082	2,322	2,709	2,745
EU	**31,383**	**27,173**	**24,954**	**25,028**	**25,424**	**25,628**	**24,054**
Russia	7,700	7,500	7,800	7,450	7,280	6,590	6,240
Switzerland	110	111	116	104	112	104	108
Turkey	650	550	200	150	135	124	220
Ukraine	2,700	2,450	2,500	2,860	2,740	2,780	2,078
Other Europe	2,390	3,953	4,117	4,244	4,219	4,322	3,944
Europe	**44,933**	**41,737**	**39,687**	**39,836**	**39,910**	**39,548**	**36,644**
Egypt	300	300	250	240	250	250	250
Mauritius	230	100	80	65	63	65	59
Nigeria	300	300	300	240	29	10	14
South Africa	4,100	3,900	3,854	3,584	3,532	3,460	3,388
Swaziland	130	127	131	131	126	115	126
Zimbabwe	250	200	220	217	212	272	257
Other Africa	1,070	960	908	920	899	877	840
Africa	**6,380**	**5,887**	**5,743**	**5,397**	**5,111**	**5,049**	**4,934**
Argentina	1,700	1,650	1,670	1,500	1,500	1,683	1,710
Bolivia	700	500	500	460	300	291	310
Brazil	167,450	160,670	146,630	147,286	126,196	115,025	106,146
Canada	2,500	2,300	2,300	2,300	2,300	2,250	2,150
Colombia	2,800	500	200	150	180	220	250
Costa Rica	400	300	300	300	300	300	300
Ecuador	700	526	526	496	320	320	378
Guatemala	800	650	650	650	650	650	550
Mexico	550	450	346	392	467	616	671
Nicaragua	290	289	271	288	282	215	265
U.S.A.	191,500	162,139	143,164	120,628	95,951	81,218	76,025
Other America	3,650	3,560	3,615	3,640	3,841	3,786	3,737
Americas	**373,040**	**333,534**	**300,172**	**278,090**	**232,287**	**206,574**	**192,492**
China	38,500	38,000	36,500	34,000	31,500	30,500	29,700
India	20,000	17,000	16,500	19,000	18,000	17,800	17,200
Indonesia	1,700	1,700	1,650	1,600	1,550	1,650	1,600
Iran	300	305	290	276	243	184	200
Japan	1,130	1,130	1,126	1,368	1,095	1,036	1,100
Korea,South	600	630	652	752	722	1,052	966
Pakistan	900	900	1,000	800	635	419	317
Philippines	840	840	840	830	780	800	800
Saudi Arabia	2,000	1,700	2,200	3,500	3,000	3,500	3,600
Taiwan	100	90	90	93	140	237	293
Thailand	4,400	3,000	2,800	2,500	1,800	1,000	600
Other Asia	1,000	800	750	720	700	670	820
Asia	**71,470**	**66,095**	**64,398**	**65,439**	**60,165**	**58,848**	**57,196**
Australia	1,800	1,250	1,250	1,400	1,600	1,500	1,500
Other Oceania	240	240	240	243	217	257	275
Oceania	**2,040**	**1,490**	**1,490**	**1,643**	**1,817**	**1,757**	**1,775**
WORLD	**497,863**	**448,743**	**411,490**	**390,405**	**339,290**	**311,776**	**293,041**

Source: *World Ethanol Markets, The Outlook to 2015, F.O.Lichts, 2006*

Annex Table 2. Macro economic and energy related indicators for Swaziland

		1981-83	1991-93	2001-03	2003
Population	million	0.587	0.887	1.070	1.080
GDP in billion of 2000 US$	billion of 2000 US$	0.567	1.078	1.445	1.472
GDP Per Person	2000 US$, MERs	967	1216	1351	1363
Total Primary Energy Consumption	Quadrillion (10^{15}) Btu	0.009	0.012	0.021	0.021
Total Primary Energy Production	Quadrillion (10^{15}) Btu	0.005	0.004	0.011	0.011
Total Primary Energy Imports, Net	Quadrillion (10^{15}) Btu	0.004	0.008	0.010	0.010
Energy self-sufficiency ratio	**%**	**53.8**	**36.8**	**54.3**	**53.8**
Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels	Million Metric Tons Carbon Equivalent	0.175	0.175	0.370	0.369
Electricity					
Total Net Electricity Generation	Billion Kilowatthours	0.261	0.404	0.393	0.392
Net Hydroelectric Power Generation	Billion Kilowatthours	0.096	0.202	0.191	0.190
Net Nuclear Power Generation	Billion Kilowatthours	0.000	0.000	0.000	0.000
Geothermal, Solar, Wind, and Wood and Waste Electric Power Generation	Billion Kilowatthours	0.000	0.000	0.000	0.000
Conventional Thermal Electricity Generation	Billion Kilowatthours	0.165	0.202	0.202	0.202
Electricity Imports	Billion Kilowatthours	0.000	0.485	0.745	0.796
Electricity Exports	Billion Kilowatthours	0.000	0.000	0.000	0.000
Net Electricity Imports	Billion Kilowatthours	0.000	0.485	0.745	0.796
Electricity Distribution Losses	Billion Kilowatthours	0.018	0.028	0.028	0.027
Total Net Electricity Consumption	Billion Kilowatthours	0.243	0.860	1.110	1.161
Total Electricity Installed Capacity	Million Kilowatts	0.081	0.122	0.126	0.131
Coal					
Estimated Recoverable Coal	Million Short Tons				**229**
Coal Production, Total	Million Short Tons	0.16	0.10	0.41	0.41
Lignite	1000 Short tons	0.00	0.00	0.00	0.00
Anthracite Coal Production	1000 Short tons	61.7	37.6	19.8	19.8
Bituminous Coal Production	1000 Short tons	96.3	62.8	386.5	385.8
Coal Consumption, total	Million Short Tons	0.158	0.100	0.406	0.406
Coal Imports, net total	Million Short Tons	0.000	0.000	0.000	0.000
Oil					
Crude Oil production	Thousand bbl/d	0.000	0.000	0.000	0.000
Petroleum consumption	Thousand bbl/d	2.000	2.959	3.520	3.500

Source: Energy Information Administration, *International Energy Annual 2003*

The Kyoto Protocol

Following the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, representatives of more than 160 nations met at Kyoto in 1997 at the third climate conference to negotiate binding limits on greenhouse gases (GHG) for developed countries. The resulting Kyoto Protocol established emission targets for each of the participating developed countries, the so-called Annex I countries.

The targets for the first commitment period (2008-12) averaged to a 5.2% reduction for the industrialized countries as a whole compared to the 1990 level of emissions. The target for the EU was 8% reduction, and those of the US and Japan 7% and 6% reductions, respectively, while some countries could increase their emissions (e.g. Iceland by 10%). The developing countries were exempt from reduction commitments.

The Protocol was subject to ratification, acceptance, approval or accession by Parties to the Convention. It entered into force in February 2005, after at least 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55 % of the total carbon dioxide emissions for 1990 from that group, deposited their instruments of ratification, acceptance, approval or accession. The US (responsible for more than 25% of the world's GHG emissions) announced in 2001 that it would not ratify the protocol, arguing that it was unfair because its mandatory targets for reducing emissions would have unduly harmed the US economy while exempting China, India and other large developing countries.

As of February 2006, 162 states and regional economic integration organizations have deposited instruments of ratifications, accessions, approvals or acceptances. The total percentage of Annex I Parties emissions is 61.6%.

The Kyoto Protocol included three innovative "flexibility mechanisms" to lower the overall costs of achieving its emissions targets, considering that the cost of limiting emissions varies considerably from region to region. Thus these mechanisms enable Parties to access cost-effective opportunities to reduce emissions, or to remove carbon from the atmosphere, in other countries. The effect for the atmosphere of limiting emissions is the same, irrespective of where the action is taken.

The three Kyoto Protocol mechanisms are:

- The clean development mechanism (CDM) defined in Article 12 provides for Annex I Parties to implement projects that reduce emissions in non-Annex I Parties, or absorb carbon through afforestation or reforestation activities, in return for certified emission reductions (CERs) and assist the host Parties in achieving sustainable development and contributing to the ultimate objective of the Convention. The CDM is supervised by the CDM Executive Board.

- The joint implementation mechanism defined in Article 6 an Annex I Party may implement an emission-reducing project or a project that enhances removals by sinks in the territory of another Annex I and count the resulting emission reduction towards meeting its own Kyoto target.

- The emissions trading mechanism, as set out in Article 17, provides for Annex I Parties to purchase units from other Annex I Parties.