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ETHANOL POTENTIAL, LAND E, FOOD AND FUEL IMPLICATIONS (PART I).

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OVERVIEW OF MAIN ISSUES

BOX 1- Current concerns

The current global debate on bioenergy particularly liquid biofuels (biodiesel and bioethanol), focuses on the overall social and environmental benefits and land e competition. New evidence has recently emerged on the overall GHG benefits of certain biofuels for which there is currently little consensus. There is also widely diverging views on the sustainability of current and future of biofuels.

It seems questionable whether previous assumptions on the overall benefits of biofuels have been robust enough given the complex nature of bioenergy e.g. the key role of agriculture, the potential impacts of climate change (i.e. longer droughts, and more severe flooding), increasing demand for food and energy, and greater environmental scrutiny. These uncertainties are turning food versus fuel into a very sensitive political issue and have created a new "reality for biofuels". This new situation requires far more credible answers

Recent studies questioning some environmental and social benefits of biofuels have intensified the debate e.g. see FAO (2007), Cruzten et al (2008), Doornnbosch & Steelblink (2007)[1], Royal Society (2008), Searchinger et al (2008. Unfortunately the general press has highlighted primarily the potential negative effects, ignoring the fundamental message.

A common feature of all these studies is that they lack rigorous long term scientific data to back up most of the claims. Worse, most of the criticisms have been blown up out of proportions by the general press and detractors of biofuels.

Much of the criticism is aimed at first generation of biofuels because a failure to fully understand the potential economic implications on commodity prices, social environment, and transport costs of the feedstocks. Although there is a lack of consensus in many issues related to biofuels, two major schools of thought can be distinguished, briefly discussed below.

[1] This document was prepared by the authors for the OECD and has been widely attributed to this organization, although it does not necessarily represents the official OECD view.

i) **The anti-biofuels lobby.** The main arguments of this lobby are:

- Large scale production of biofuels will lead to food insecurity worldwide
- Increasing food prices will affect particularly the poorest people in developing countries
- Land competition will greatly increase as demand for food and non-food products intensifies. This will lead to deforestation, destruction of ecosystems, biodiversity and so forth. This view tends to ignore potential land availability from existing non-forest land which could be ed for biofuel production without affecting food production, simply by reforming and modernize agriculture
- Many of the befits of biofuels e.g. social and environmental, are not yet fully proven

ii) **The pro-biofuels lobby,** major arguments:

- There is sufficient land available to produce food and a reasonable proportion of biofuels (i.e. 5/10-20% of transport fuels demand) without affecting food supply. The main problem is social injustice, unequal distribution of food, etc (see Sect. 5). Biofuels are not the panacea but are currently the best available alternative
- Synergy between biofuels and agriculture is mutually beneficial and can enhance food production
- On balance, the social, economic, and environmental benefits of biofuels outweigh potential negative impacts, if good management practices are applied

BOX 2- Land e availability

There should be sufficient land for a substantial increase in production of biofuels and food with land reform and agricultural modernization.
There are almost 2 Gha abandoned farmland compared to 1.4 Gha used farmland today (FAO statistics), although some of this area may be difficult to cultivate because of lack of water, salinity or other causes. The most conservative estimations leave some 440 Mha for biofuels (Doornnbosch & Steelblink, 2007) or 700 Mha (Homan, 2007), but other estimates vary widely.

Issues of social and political responsibility are at stage e.g. to make sure that not economically strong companies buy the best land for biofuels and leave the less profitable land for locals; or to ensure the environmental sustainability of biofuels, which will be a major challenge. There land available sufficient to replace at 5% to 20% of transport fuels by biofuels, without affecting food production, provided the right policies are put in place. Other higher estimates are perhaps not very realistic.

The production capacity is partly dependent on whether cellulosic ethanol is included or not. Bergsma et al. (2007) have estimated that replacing 20% of oil for transport e (88EJ) in 2020 by liquid biofuels will require between 150 Mha to 1000 Mha, while Woods (2007) and Moreira (2006) estimates range between 80 and 250 Mha, when using selected advanced conventional biofuel production technologies (e.g. sugarcane derived bioethanol) to meet about 30% by 2020).
None of these authors have estimated what capacity forest would add.

See Sections 3 & 5

BOX 3: Impacts on food prices

To what extent food price increases are the direct consequence of biofuels demand? Price increases due to *direct land competition* is a myth rather than a reality considering that merely about 1% of the global land area is currently dedicated to biofuels. There are complex reasons for food price increases that often have little to do with biofuels expansion. For decades farmers have seen their income falling as the prices of agricultural commodities have kept falling year after year.

Higher agricultural prices have both positive and negative impacts e.g. higher incomes will allow farmers to invest more in agriculture and bring under cultivation new lands previously abandoned as uneconomic for lack of market. 70% of the world's poor live in the countryside and could therefore benefit more directly from price increases. Also, higher food prices can also be compensated by lower energy cost of food production. But the urban poor face a grim future if prices are high and this requires policy action.

The cost of the raw material plays a comparatively small role in the retail of food since price increases are largely determined by commercial and other issues rather than by the raw material. For example, a 50% increase in the cost of raw materials in the US leads approx to 5% increase in the commercial price of bread and breakfast cereals while other corn-based products (processing, packaging and distribution) accounts for 90%.

Price increases are exaggerated by the popular press, a strategy often ed by critics to scare off consumers. The greatest impacts are caused by oil price increases, as oil is ed in the whole production and distribution chain, rather than by biofuels. On the whole, farmers aren't necessarily the main beneficiaries as they are often squeezed-out by traders

See Section 6

BOX 4: Subsidies

One of the major problems is to identify many of the hidden subsidies that fossil fuels receive directly or indirectly in a multitude of forms. For example, in the US the petroleum industry has received between $135 billion (BI) to $150 BI in tax breaks from 1968 to 2000, excluding foreign investment tax credits, compared to $7.7BI to $11.6BI given to the ethanol industry from 1979 to 2000. When direct and indirect subsidies are included, it is estimated they represent more than $0.30cents per litre of gasoline. In the ethanol producers and blenders share a $51cents/gal Federal credits ($2B/yr costs), the majority of which accrues to oil companies, not farmers (see GAO, 2000; WI, 2007).

Yet, one of the major criticisms against ethanol and biodiesel, are the subsidies paid by governments to develop this industry which, critics say distort the market. The scrutiny to which bioenergy is being subjected is unprecedented, and critics often forget that, historically, fossil fuels have received, and continue to receive, huge subsidies. While most of these fossil fuels subsidies continue, there are increasing calls to remove or reduce subsidies to the bioenergy industry, which are very small by comparison.

See Section 7

BOX 5: Energy balance

The energy balance of ethanol production (the ratio of energy contained in the biofuel to the ratio of fossil fuel energy ed to produce it), is still a contentious issue despite numerous studies. It is also an issue often grossly oversimplified given the complex web of economic, social and political factors that need to be taken into account; different calculations and assumptions can, therefore, lead to vary different conclusions.

Detractors of biofuels are constantly remaining us that you *put more energy in than take out*, often quoting old data, ignoring new lower inputs, general improvements, productivity increases, and increasing e of non-fossil fuels in the ethanol production processes, or simply distorting or using inaccurate data.

It is also interesting to note that opponents of ethanol often ignore the energy balance of gasoline which is negative. According to the GREET Model calculations, the fossil energy input per unit of ethanol is 0.78 MBTU of fossil energy consumed per each 1 MBTU of ethanol delivered, compared with 1.23 MBTU of fossil energy consumed for each MBTE of gasoline delivered (www.transpsortation.anl.gov/)

Despite considerable disagreement, some consensus is emerging. For example for corn, the energy balance varies from 1.25, 1.34 and 1.35, which could be further improved to 2.9 if fossil fuels ed in industrial processes are switched to biomass-based fuels. US corn is, however, one of the least efficient feedstocks ed in ethanol production e.g. sugarcane from Brazil has a ratio is 8.3 to 10 fold.

See Section 8

1. Introduction

The growing demand for bioenergy has sparked off a debate, particularly with regard to the possible negative social and environmental implications. Although many of the possible impacts are rarely the direct consequence of bioenergy, how they are perceived by the general public, real or not, can have major impacts on the future direction of biofuels. The areas of greatest concern, at least with first generation of liquid biofuels, are land competition, impact on food prices, biodiversity, sustainability and subsidies. The growing concern with liquid biofuels is as a consequence of the pressure to reduce the overwhelming dependency on oil for transportation and the speed they are being introduced, without the necessary political changes in the agricultural sector.

Part One of this paper looks at: i) estimates of biomass energy potential, ii) land availability for bioenergy production, iii) ethanol production and utilization potential,

iv) major concerns with food versus fuel (land e competition, food prices and subsidies), v) energy balance, iv) employment and biotrade), and vii) agricultural and feedstock issues[2]. Part Two deals with environment, genetically modified crops, water e and sustainability issues.

2. Overview of estimates of biomass energy potential

Bioethanol production cannot be separated from the overall biomass for energy scenario. It is also very important to distinguish between theoretical, technical and economic potential, as this can vary enormously[3]. This is something the general public often fails to understand. For example, according to Rao & Hall (1999) The captured solar radiation is converted by the world's terrestrial and aquatic ecosystems into roughly 220 billion tonnes of dry biomass annually with an energy content of 4,500 EJ (108000 Mtoe), 10 times greater than the rate of global primary energy consumption by humans. And the gross theoretical annual bioenergy potential is about 2900 EJ (1700 EJ from forests, 850 EJ from grasslands, and 350 EJ from agricultural areas), though only 270 EJ could be considered economically viable on a stainable basis.

There have been many attempts to estimate the biomass energy potential, but each study has come up with different projections partly due to insufficient long term reliable data and assumptions. Many projections are of a speculative nature and should therefore be treated with considerable caution. For example, estimates of primary energy supply that could be available from dedicated energy crops, residues and wastes range from 0 to 2052EJ for energy crops and 33-76EJ for residues and waste (Junginger et al (2006) (see also Fig. 1).

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[2] See also the short paper F. Rosillo-Calle (2007) entitled "Biofuels versus Fuel: Old Myths and Misconceptions, distributed to BEST Partners

[3] The theoretical potential refers to the total volume of biomass; technical potential refers to the total volume of biomass that could be recovered with existing technologies; economic potential refers to the volume of biomass that is economically competitive with other non-biomass sources, and it should take into account environmental sustainability. The economically potential of biomass energy is always a small fraction of the theoretical potential.

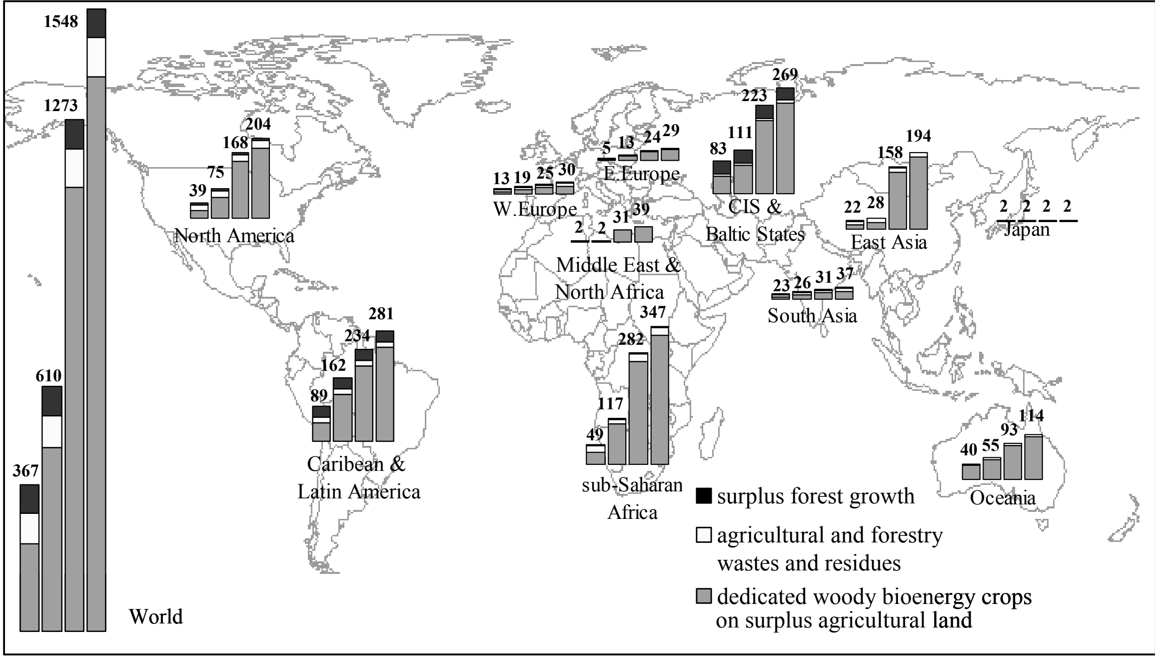

Figure 1: Total bioenergy production potential in 2050, agricultural production systems scenarios 1 to 4. The numbers above the bars are EJ/yr.

Source: Junginger at al (2006).

Table 1 summarises the primary energy supply potential technically available by region, as estimated by Doornnbosch & Steelblink (2007).

Table 1: Estimated biomass and biofuels potential in 2050 (oven-dry, EJ/year)

Region	Potential from additional land	Crop residues potential	Forest residues potential	Animal & organic waste	Total biomass potential primary energy	Total biofuel potential after conversion
	(1)	(2)	(3)	(4) (a)	(5) (b)	(6) (c)
N. America	0.7	5.0	14.3	0.5	20.5	3.6
S& C America	62.0	4.3	16.8	0.9	84.0	14.7
Europe & Rsia	10.1	5.8	16.9	1.1	33.9	5.9
Africa	43.8	6.3	18.2	1.4	69.7	12.2
Asia	-18.6	12.6	20.6	6.0	20.8	3.6
Oceania	11.2	0.6	3.8	0.1	15.7	2.7
World Total	**109.2**	**34.8**	**90.6**	**10.0**	**244.6**	**42.8**

Notes:

(a) Regional distribution is assumed to be proportional to population

(b) 5 = (1)+(2)+(3)+(4)

(c) 6 = (5)x0.50.35; assumes 50% biomass is ed for biofuels, and conversion efficiency of 35%

Source: Doornnbosch & Steelblink (2007)

3. Estimates of land availability for energy production

There remain many unanswered questions with regard to the total land availability suitable for dedicated energy crops and agricultural land. These issues have been debated and researched by many scholars but the reality is that only rough estimates are possible given the many variables involved and lack of long-term scientific data. Additional uncertainties include the long-term productivity and sustainability of energy crops production, the effect of population growth and changing diets on global markets for food and animal feed; efficiency of biomass conversion technology, increased need for water and fertilizers and demand for other non-energy uses of land; and climate uncertainties.

Table 2 summarises some estimates of land potential availability for bioenergy production and other uses. The most productive land is already ed (1.5 Gha[4] arable land, 3.5 Gha grasslands, 0.2 Gha are ed for human settlements, 3.9 Gha forested land and 4.2 Gha consist of deserts, mountains and other unsuitable land for productive e (Doornnbosch & Steelblink, 2007). These authors estimate that the upper technical limit of land availability for dedicated energy plantation in 2050 would be 440 Mha. Homan (2007) estimates that there are more than 700 Mha of good quality land in 95 countries currently uncultivated which could be used for bioenergy production[5].

For the transport sector Bergsma et al. (2007) have estimated that replacing 20% of oil for transport e (88EJ) in 2020 by liquid biofuels will require between 150 Mha to 1000 Mha depending on the technological options adopted for its production. Woods (2007) and Moreira (2006)estimates range between 80 and 250 Mha, when using selected advanced conventional biofuel production technologies (e.g. sugarcane derived bioethanol) to meet about 30% by 2020). For comparison, there are approximately 260 to 219 Mha dedicated to wheat production in 2007/08 (see www.fas.da.gov).

[4] 1 Gha = 1000 Mha
[5] According to Hausman (2007) today's oil production represents the equivalent of 500 to 1000 Mha (depending of the assumptions and productivity per ha, of biofuels.

Table 2: Potential availability of land for bioenergy production in 2050 (Gha).

	Total land area	Potential for rain fed cultivation	Land potential under forest	ed arable land	Additional needed for food + other es (2003-50	Gross additional land available	Potential additional land available
	(-)	(1)	(2)	(3)	(4)	(5)= (1,2,3,4)	(5) (1-% needed for grassland
North America	2.1	0.4	0.1	0.2	0.0	0.00	0.00 (0%)
S+C America	2.0	0.9	0.3	0.1	0.25	0.25	0.25(0%)
Europe +Rsia	2.3	0.5	0.1	0.2	0.0	0.08	0.04(50%)
Africa	3.0	0.9	0.1	0.2	0.1	0.44	0.18(60%)
Asia	3.1	0.5	0.0	0.6	0.1	-0.07	-0.07(n/a)
Oceania	0.9	0.1	0.0	0.1	0.0	0.04	0.04(0%)
World Total	**13.4**	**3.3**	**0.8**	**1.5**	**0.3**	**0.74**	**0.44**

For further details see Doornnbosch & Steelblink (2007)

FAO statistics[6] show there are about 2 Gha of land considered degraded or abandoned which could represent an excellent opportunity to re-invigorate the most productive land[7]. A good proportion of this land could be brought under cultivation with relatively low investment as land is often abandoned not because of low productivity but mostly due to low prices of commodities, lack of markets, infrastructure, finance, capital, skills and so forth.

The largest land availability for biofuels could come from underutilised, pastures and grasslands (rather than from forested land as is often portrayed), combined with better utilization of residues. However, based on present trends, it is unlikely that large amounts of land would be available for dedicated energy crops without fundamental changes in the agricultural sector (see Sect. 9). The challenge is how to achieve greater stainable productivity per hectare/year with the lowest possible inputs. An even a greater challenge and uncertainly is how to deal with the possible potential impacts of climate change.

[6] FAOSTAT - Food and Agricultural Organization, UN, Rome

[7] It is accepted that degraded land posses a serious challenge since this land is often of poorer quality and will result in higher costs and lower productivity. This, of course, could be partly counterbalanced by its greater environmental and ecological benefits.

Other limiting factors may be difficulties to cultivate certain lands due to lack of water, salinity, lack of investment, lack fair play, etc. The modernization of bioenergy must be in parallel with educational and agricultural change and capacity building.

4. Bioethanol potential

Global ethanol production in 2005 reached 45Bl of which about 33 Bl were used as fuel [equivalent to approx. 17.6 Mtoe (0.74 EJ), or approximately 2% of global gasoline consumption] and the rest was used in the beverage and other industrial applications (Berg, 2004). Global ethanol production in 2006 has been estimated as 51 Bl of which about 39 Bl was used as fuel (www.rfa.org). Brazil and the US have dominated ethanol production and utilization, representing more than 80% of the market. In 2005 about 60% of ethanol production was from sugarcane, 30% from grains (mostly corn), 7% from synthetic ethanol (from ethylene, coal, etc) and 3% from other feedstocks.

Ethanol production and demand has grown rapidly since 2000, spearheaded by demand created by policies rather than by genuine market forces, mainly in the US and in Europe (e.g. France, Germany and Spain). The number of countries that have introduced or have shown interest in introducing fuel ethanol is growing constantly e.g. currently there are more than 40. In most countries ethanol is blended with gasoline in proportions that vary from 2% to 10% (volume basis), except in Brazil where this proportion varies between 20-25%. In addition, Brazil is the only country where neat ethanol vehicles are still used in large scale. Brazil is also unique because more than 80% of all new passenger cars sold in 2007 were FFVs[8]

4.1 Global estimates of fuel ethanol demand

Various studies have attempted to come up with global estimates of ethanol fuel production and e, but with large variations. For example, Walter et al (2008) have developed a model to assess potential fuel ethanol consumption by 2030 using historic data of gasoline consumption in the major countries and regions e.g. US, EU-

[8] FFVs ethanol gasoline blends vary, depending on the price of ethanol-gasoline ratio. It is common to put 50% ethanol + 50% gasoline. Since in Brazil gasoline has to be blended with 20-25% ethanol by law, this means that ethanol represents 70-75% by volume in this case.

25, Japan, China, Brazil and the rest of the World (ROW – BR)[9]. Total gasoline consumption was estimated as 1,213 Bl in 2005. The forecast procedure is based on extrapolation of current trends of gasoline consumption in each country or region. Table 3 summarises estimates of potential fuel ethanol production by major regions from 2005 to 2030 according to Walter et al (2008). (See also Fig. 2).

For Brazil a different procedure was used, as gasoline demand is strongly influenced by the flex-fuel vehicles (FFVs). Estimates of the ethanol market were used for the period 2010-2015. It was assumed that the share of ethanol fuel will reach almost 55% (volume basis) in 2020 and then stabilize thereafter (see Walter et al (2008) for further details.

Table 4 presents estimates of total ethanol production by feedstock from 2010 to 2050 (see Fulton 2004). Fulton's scenario is rather optimistic with shares of gasoline demand replaced by ethanol representing 5% in 2010, 13% in 2020, 25% in 2030 and 54% in 2050. Another salient feature is that ethanol from cellulose becomes the most important feedstock from 2020 onwards which is highly unlikely.

Table 3: Estimates of fuel ethanol production, in Bl (billion litres)

Region/country	2005	2010	2020	2030
Conventional feedstocks				
US	16.2[1]	45.0[a]	58.0[b]	63.0[b]
EU-25	2.1[2]	9.5[c]	24.8[d]	40.0[d]
China	1.3[3]	2.5[4]	12.6[4]	18,2[e]
ROW-BR[f]	1.0	2.5	6.0	10.3
Brazil	18.0[5]	26.0[6]	44.7	62.0
World	38.6	85.5	146.1	193.5
Cellulosic materials				
US	---	---	9.0[g]	178.0[7]
World	---	---	9.6[h]	203.0[8]

Sources: See Walter et al (2008) for further details
Notes:
[a] Authors estimates based on predicted production capacity of 40-42 Bl by 2009
[b] Authors calculations based on adjusted function of recent data production capacity of estimates by 2010 and on the hypothesis that ethanol production from corn will reach 55 Bl by 2017;
[c] Authors assumptions based on predicted production capacity of 7.7 Bl by the end of 2008
[d] Authors calculations based on an adjusted function to the current production capacity and future capacity estimates.
[e] Authors estimates based on an adjusted function to estimates of the previous years;
[f] Authors assumptions (all years);
[g, h] Authors calculations based on an exponential function adjusted to the estimate by 2030, assuming small-scale commercial production starting in 2012.

[9] This group comprises a large number of countries with heterogeneous features regarding their importance as gasoline consumer and as fuel ethanol producers

Ethanol

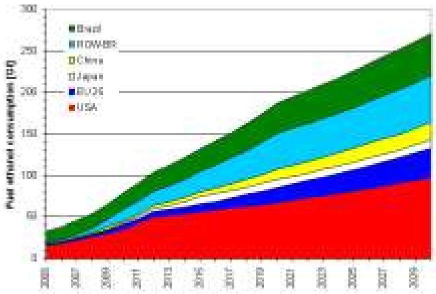

Table 4: Ethanol potential production from different feedstock (BI)

Country/region and feedstock	2010	2020	2030	2050
Brazil – ethanol from sugarcane	21.0	61.3	121.2	309.6
Other LA – ethanol from sugarcane	4.4	24.2	42.7	59.8
India – ethanol from sugarcane	5.9	23.6	49.7	100.6
Africa – ethanol from sugarcane	1.6	16.6	35.6	65.9
Asia, except China – from sugarcane	5.6	19.8	31.2	54.4
China – ethanol from sugarcane	1.9	7.6	16.0	38.6
Middle East– ethanol from sugarcane	0.3	1.2	2.0	3.7
World – ethanol from sugarcane	40.7	154.3	298.4	632.6
EU – ethanol from grain + beet	12.1	27.3	27.3	27.3
North America – ethanol from grain	28.9	68.2	68.2	68.2
Rest of the World – ethanol from grain	4.6	10.6	10.6	10.6
Ligno-cellulose ethanol	0.0	21.2	203.0	1,036.4
Total from all feedstocks	86.3	281.7	607.6	1,775.1
Share of estimated gasoline demand	5%	13%	25%	54%

Source: Fulton (2004)

5. Concerns on fuel versus food and land availability

The current global debate on bioenergy particularly liquid biofuels (biodiesel and bioethanol) focuses on the overall social, environmental benefits and land use competition. The argument is that in the rush to substitute oil, many issues have been overlooked and need a fresh re-think. It seems that previous assumptions have not been robust enough given the complex nature of bioenergy. The potential negative effects have been extensively reported and misreported.

Production of large-scale of biofuels is far more complex that it seems given the key role of agriculture, the potential impacts of climate change (i.e. longer droughts, and more severe flooding), increasing demand for food and energy, and greater environmental scrutiny, requires far more credible answers. The uncertainties on possible impacts on food supply together with the overall social and environmental benefits are turning food versus fuel into a very sensitive political issue.

The debate has intensified partly because the concerns with the rapid production of biofuels, primarily in the and EU, has not been accompanied by good management practices, with the results that international organizations such as FAO (2007) or Royal Society (2008), have raised considerable doubts on the overall benefits of bioenergy, particularly liquid biofuels, not to mention countless other organizations (e.g. see Doornnbosch & Steelblink (2007)[10], International Institute of Stainable Development [(IISD, www.iisd.org); Kutas et al 2007 and Koplow, 2007)][11].

Much of the criticism is aimed at first generation of biofuels because a failure to fully understand the potential economic implications on commodity prices, environment, social, transport costs of the feedstocks, infrastructure, rapid demand in some producing countries such as the , and so forth.

[10] This document was prepared by the authors for the OECD and has been widely attributed to this organization, although it does not necessarily represents the official OECD view.

[11] The general press is constantly reporting on bioenergy, particularly on ethanol and biodiesel, and in most cases very superficially. For example, Jean Ziegler, a former UN expert who calls the production of fuel rather than food "a crime against humanity" See Intern Herald Tribune (www.iht.com/bin/8074319, of 01/11/07. Reporting on the rapid expansion of biodiesel in Colombia see Nicholls K, and Campos E, article "Are you driving on blood fuel?, Ecologist Vol. 37(7) Sept/07 pp 44-48. Such criticism is highly irresponsible.

Given the large differences in costs and benefits of different biofuels (i.e. type of cultivation methods, feedstock, conversion technology, geographical distribution, and even cultural factors), combined with lack of knowledge on many issues, diverse policy objectives and business interests, it should not be surprising that different views are emerging. It is important that these issues are further investigated to avoid providing a short solution to a problem while creating many more on the longer term.

World food consumption patterns are full of mismanagement, over consumption and waste in rich countries, and under nourishment in poor countries. People do not go hungry because lack of food but because they cannot afford to buy it due to factors such as social inequality, unjust land tenure, wars, poor agricultural management, lack of capital and skills, and so forth. As Hazel & Wood (2007) put it *".., more food is produced than needed to feed the entire world population and at prices that have never been so low. The fundamental hunger problem today is one of income distribution rather than food shortages".*

Given the right conditions, farmers have shown they can produce far more food than thought possible. Farmers' ability to provide food and fuel if the price is right should not be underestimated. The development of new technologies, combined with improvements in yield, and better utilisation of fertilisers, indicates that it is possible to produce far more food, feed, and biofuels. Many farmers in poor countries do not own land and lack capital, skills and the finance to purchase machinery and fertilisers. If these farmers have access to the same resources and markets as farmers in more developed countries, agricultural production could increase quite significantly without bringing into production new land. This will be particularly so if women in many developing countries, particularly in Africa, where given access to these resources and greater freedom.

6 Impacts on food prices

To what extent food price increases are the direct consequence of biofuels demand? There are a complex web of reasons for food price increases, often little to do with biofuels expansion, e.g. in the US has been the rapid demand for ethanol from corn driven by policy, short term investment objectives and speculation.

For decades farmers have seen their income falling as the prices of agricultural commodities have kept falling year after year[12]. The impact on the farming community, particularly in poor areas of developing countries, has been dramatic, reflected in massive migration to urban centres as living standards in rural areas continued to decline with all the social, economic and environmental implications that it entails.

On the whole, the cost of the raw material plays a comparatively small role in the retail of food since price increases are largely determined by commercial and other issues rather than by the raw material. For example, a 50% increase in the cost of raw materials in the US leads approx to 5% increase in the commercial price of bread and breakfast cereals while other corn-based products (processing, packaging and distribution) accounts for 90%[13]

Too much emphasis is being placed on short-term issues (e.g. short-term grain price increases) giving insufficient time for market forces to adjust. Higher agricultural prices have both positive and negative impacts. For example, higher incomes will allow farmers to invest more in agriculture and bring under cultivation new lands previously abandoned as uneconomic for lack of market. This can also lead to lower agricultural subsidies both of which, together with increase investment, might stimulate greater production efficiency. Modernisation of agriculture will also lead to greater overall production. Increasing investment on modern scientific research for agriculture led to dramatic yield breakthroughs in the last century e.g. in England wheat yields took nearly 1000 years to increase from 0.5 to 2 t/ha/yr, but jt 40 years to increase to 6 t/ha/yr (Hazel & Woods, 2007).

Inevitably consumers will have to pay more for food with the poorest being most vulnerable and therefore some safe mechanisms should be put in place to avoid the worst effects on the poor; this requires primarily political solutions. In developed countries people have been paying a very small share of their income on food, and this would not be realistic in the future.

Higher food prices can also be compensated by lower energy cost of food production. 70% of the world's poor live in the countryside and could therefore benefit

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[12] For example, in the UK if wheat prices kept pace with inflation over the past century, wheat would now be worth about $1200/t, rather than it current price of $190/t. See Biofuels-Some Myths and Misconceptions, National Farmers Union, UK (www.nfuonlie.com).
[13] See also www.novozymes.com/files/documents/thematic (Biofuel thematic paper: Food versus Fuel)

more directly from price increases. Further, high agricultural prices will slow down the penetration rate of biofuels, and in worst cases make them uncompetitive as other alternatives may also emerge.

Price increases are exaggerated by the popular press, a strategy often used by critics to scare off consumers. It is also important to keep in mind that the greatest impacts are caused by oil price increases, as oil is used in the whole production and distribution chain, rather than by biofuels. On the whole, farmers aren't the main beneficiaries as they are often squeezed-out by traders[14]

The EC (2007) has estimated the potential impacts on commodity prices of non-biofuel e, together with a 7% and 14% share of biofuels e. It shows that without biofuels wheat prices, for example, will decline by 8% compared to 2006 average prices, minor 1% with 7% biofuels and pl 6% increase with 14% share of biofuels and at the same time decrease fuel prices by 3%, as illustrated in Table 5.

Table 5: Relative price change with and without biofuels e, compared to 2006 average price (Euro/t) of various commodities in the EU

Commodity	Scenario (in percentages)		
	No biofuel e	7% share biofuels	14% share biofuels
Common wheat	- 8	-1	+6
Rape meal	+45	- 37	-42
Rape oil	-49	+3	+13
Soy meal	+19	-30	-39
Soy oil	-32	+43	+54
Wood*		0	0
Oil**		-1.5	-3
Glycerine*			

Notes: * No expected price effect; ** Change relative to non-biofuel e
See EC (2007) for further details

The International Food Policy Research Institute (IFPRI) has also attempted to predict impact of biofuels on food prices up to 2020, using two major scenarios. Scenario 1 is based on current investment plans and predicts an increase of maize by 26% and that of oilseeds by 18%. Scenario 2 assumes that biofuels will reach double the extension of scenario 1, and found that price increase for maize will

[14] For example, to the Renewables Fuel Association (RFA) a $1 increase in the price of gasoline will results in a 0.6 to 0.9% in consumer food prices, compared to 0.3% increase resulting from a $1 rise in the price of corn (www.CNNMoney.com/comentary). This is because gasoline/diesel price increase has stronger impacts as fossil fuels are ed in all processing and distribution chain.

increase by 72% and oilseeds by 44%. In both scenarios crop princes are hardly dependent on the availability of land for food production, with poor people spending 50-70% of their budget on food[15]. The World Bank (WB, 2008) also recognises that increase in food prices is likely to persist at least until 2015 until supply and demand respond to higher prices.

Increase on food prices poses a dilemma: i) higher agricultural products will bring many benefits to farmers/rural community by making more profitable agriculture (70% of the world's poor live in rural areas); ii) but the poor in urban areas face a grim future, unless policy mechanisms are put in place to protest the most needed from high food prices.

7 Subsidies

One of the major problems is to identify many of the hidden subsidies that fossil fuels receive directly or indirectly in a multitude of forms. Take, for example, the US where a report by the General Accounting Office (GAO) shows that the petroleum industry received between $135Bl to $150Bl in tax breaks from 1968 to 2000, excluding foreign investment tax credits estimated to cost de Treasury a further $7Bl per year, compared to $7.7Bl to $11.6Bl given to the ethanol industry from 1979 to 2000 (GAO, 2000; WI, 2007).

US subsidies to the petroleum industry equal to approx. $0.003cents/litre, but when indirect subsidies are included (i.e. military expenditure related to secure oil supplies from the Persian Gulf, which in 2003 amounted to c$50 billion), this represents an additional $0.30cents/litre of gasoline (see WI, 2007), excluding environmental damage of transport fuels[16].

In 2006 the US Federal energy subsidies totalled approx. $74Bl, of which fossil fuels accounted for $49Bl (66.2%) compared to $6Bl for ethanol (7.6%). See Doornbosch & Steenblik, 2007; www.earthtrack.net. Table 6 also shows subsidies paid to biofuels (bioethanol and biodiesel) and petrol and diesel equivalent, per litre. In the US ethanol producers and blenders share a $51cents/gal Federal credits ($2B/yr costs), the majority of which accrues to oil companies, not farmers.

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[15] Quoted in www.scidev.net, 25 March 2008

[16] For example, environmental damaged caused by diesel in the transport sector in 1993 (the year for which data is available), has been estimated at $0.31cents/litre (see WI, 2007).

Yet, one of the major criticisms against ethanol and biodiesel, are the subsidies paid by governments to develop this industry which, critics say distort the market. The scrutiny to which bioenergy is being subjected is unprecedented, and critics often forget that, historically, fossil fuels have received, and continue to receive, huge subsidies. While most of these fossil fuels subsidies continue, there are increasing calls to remove or reduce subsidies to the bioenergy industry, which are very small by comparison.

Table 6: Subsidies paid to bioethanol and biodiesel in the EU and US, in 2006 (in billions and per litre)

	Bioethanol	Biodiesel
EU (total) -Support per litre petrol or diesel equivalent	E1.29 ($1.87) (Billions) E/l 1.10 ($1.59)*	E2.43 ($3.52) (billions) E/l 0.55 ($0.79)
US (total) - Support per litre petrol or diesel equivalent	$5.8-7(E4-4.82) (billions) $0.37-0.45 (E0.25-0.31)**	$0.53-0.65(E0.36-0.44 (Bl) $0.60-0.74(E0.41-0.51)

*E1 (Euro) = $US1.45 (Current exchange rate, 09/11/07); ** $1US = 0.69 Euros

Sources: Kutas et al, 2007; Koplow, 2007

8 The energy balance

The energy balance of ethanol production (the ratio of energy contained in the biofuel to the ratio of fossil fuel energy ed to produce it), is still a contentious issue despite numerous studies, at least as far as ethanol from maize is concerned [e.g. see Wu et al (2006), Shapouri et al (1995), Shapouri et al (2002) Wang, Wu & Huo (2007)]. It is also an issue often grossly oversimplified given the complex web of economic, social and political factors that need to taken into account; different assumptions/calculations can, therefore, vary significantly.

Detractors of biofuels are constantly remaining us that you *put more energy in than take out*, often quoting old data, ignoring new lower inputs, general improvements, productivity increases, and increasing e of non-fossil fuels in the ethanol production processes, or simply distorting or using inaccurate data. *"In addition to simply over-counting the energy e in producing ethanol, detractors fail to recognise the significant gains in recent years in yields, and energy e in processing. Modern* *ethanol plants are producing 15% more ethanol from a bushel of corn, and using 20% less energy than five years ago"*[17]

It is also interesting to note that opponents of ethanol often ignore the energy balance of gasoline which is negative. For example, a study by Sheehan et al (1998), sponsored by the USDA and USDOE, found that the primary energy use for each 1MJ of petroleum diesel requires 1.2007MJ, corresponding to 83.28% energy efficiency. Petroleum diesel uses 1.1995 MJ to produce 1MJ of the fuel product energy. According to the GREET Model[18] calculations, the fossil energy input per unit of ethanol is 0.78 MBTU[19] of fossil energy consumed per each 1 MBTU of ethanol delivered. This compares with 1.23 MBTU of fossil energy consumed for each MBTE of gasoline delivered (see www.transpsortation.anl.gov/)[20]

Despite considerable disagreement, some consensus seems to be emerging on the energy balance. For example for US corn, it is more generally accepted to be from 1.25, 1.34 and 1.35, which could be further improved to 2.9 if fossil fuels ed in industrial processes are switched to biomass-based fuels. Major improvements (i.e. reducing energy consumption, greater energy self-sufficiency, developing new co-products, etc), will further improve the energy balance. US corn is, however, one of the least efficient feedstocks used in ethanol production e.g. sugarcane in Brazil has a ratio of 8.3 to 10 fold (see Macedo et al 2004; Walter et al. 2008).

9 Employment and bioenergy trade

Employment opportunities have long been recognized as being a major advantage of biomass energy because of the many multiplying effects, strengthening the local economy. However, this is a complex issue since it is important to take into account the net job creation, job quality, etc, rather than the total employment generation. Table 7 shows employment generation in Brazil which, as can be appreciated in the case of ethanol, is 20 times cheaper than in the chemical and petrochemical sectors.

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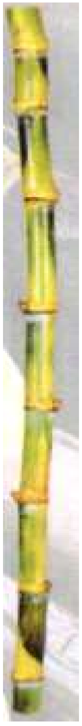
[17] www.ethanolacrossamerica.net; Issue Brief- Net energy balance of ethanol production, fall, 2004

[18] GREET- The greenhouse gases, regulated emissions and energy e in transportation, was developed by Dr Michael Wang, Argonne National Lab's Centre for Transportation Research, with support from the USDOE.

[19] Million British thermal unit (one Btu = 1.05506x 10^3J). In this case, 823 MJ for ethanol against 1298 for gasoline

[20] See document: Ethanol- The complete energy life cycle picture, 2007

However, labor intensity is not necessarily the solution, particularly in the case of modern bioenergy applications, since this will increase costs.



COST OF CREATING PERMANENT JOBS IN BRAZIL

INVESTMENT PER PERMANENT JOB

SECTOR	**INVESTMENT** (in USD per job)	**RATIO** (to ethanol)
Chemical and Petrochemical	220,000	20,1
Metallurgy	145,000	13,3
Capital Goods	98,000	9,0
Automotive (Industry)	91,000	8,3
Consumer Durables	70,000	6,4
Consumer Goods	44,000	4,0
Ethanol	10,918	1,0

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Table 7- Investment costs per permanent job in Brazil[21].

In Brazil workers in the sugar and ethanol industry receive, on average, at least 2-3 times the minimum salary, depending of the nature of the job. This is not because employers are more compassionate, rather this is dictated by market forces which, because there are other more attractive jobs elsewhere, there is a need to attract and keep workers by paying higher wages. The "boias frias" (cane cutters) is a good example, as it is a hard temporary job, with very low prestige, associated with uneducated people; younger people do not wish to be associated with type of jobs. This is currently a major driver to mechanise sugarcane harvesting!! Nonetheless, it is clear that biofuels can play a significant role in generating employment and economic activity in the countryside, as demonstrated in Brazil and US[22].

[21] Information provided by UNICA (www.unica.com.br)

[22] Milton Copulos, President of the National Defence Council Foundation, estimated that oil addition is costing the country more than $500 billion and is depriving the country of more than 2.2 million potential jobs, of which many of them could be generated by the biomass industry (www.ndfc.org)

9.1 Bioenergy trade

The Walter et al (2008 & www.bioenergytrade.org) studies show that international bioenergy trade is essential to ensure the sustainability and low cost ethanol fuel and to increase the share of biofuels as most major consumers lack the capacity to produce ethanol in large scale. Therefore it is necessary to foster production in developing countries, and this requires the removal of trade barriers and to advance towards a fair definition of sustainability criteria. It is fundamental to remove artificial barriers and let the market to play much greater role in determining the right and fair price rather than the governments. It is illogic to tax biofuels while fossil fuels do not have any trade barriers or any other restrictions.

Competition should be encouraged, but there must be a fair playing field and fair international biotrade has a big role to play. “Ethanol market expansion could also further contribute to climate change if trade barriers are removed”[23].

10 We need a new agricultural model

World demand for energy continues to grow while supply of cheap and clean energy are dwindling; at the same time population also continues to grow and so does the demand for improving living standards. What then could be the potential role of agriculture in meeting such demand without jeopardising its primary role of providing food? What would be the economic, social, political, and environmental consequences? There have been many studies attempting to answer some of these difficult questions (e.g. see Brown 2007), but with few convincing answers so far.

Agriculture has suffered from chronic under investment in most parts of the world; agriculture has faced many challenges through history but it has been able to adapt to human needs through innovation and diversification (e.g. see Mazoyer & Roudart, 2006). But its increasing global role as potential provider of many raw materials other than food products could attract massive new investment, creating many new opportunities for innovation and diversification which could truly transform the agricultural sector as we know it. How this increasingly complex situation is managed will be crucial. We need a modern and dynamic agricultural sector because

[23] Robert Zoelick, President of the World Bank

traditional agricultural cultivation methods would not be able to provide many of the requirements modern society is increasingly demanding.

Give the farmers the right conditions and they will be able to produce far more food, energy and industrial products. Think of the poor African farmer, only if he/she could have access to the same conditions farmers have in the industrial countries! This requires many fundamental changes e.g. land ownership, fair distribution, good educational level availability of capital, skills, finance, marketing knowledge, and so forth (farming cannot be seen as a backward activity, but as a modern, science driven industry).

There is a real danger of superimposing a new reality into an existing agricultural model without the fundamental changes required in the way we produce, distribute, and process agricultural products. For example, if biofuels were to be produced in large scale, which is highly unlikely, this could lead to land concentration since this seems almost a prerequisite for economic viability. There is increasing evidence which shows that most environmental impacts of biofuels can be attributed to the production of the feedstocks (see Zah et al 2007).

The main long-term difficulty facing bioenergy is not process technology but the costs of the feedstock which in the case of liquid biofuels still represent about 60-65% of total costs for sugarcane, over 70% for corn and more than 85% for most feedstocks ed in biodiesel production. It is simply not possible to have a modern and efficient bioenergy industry until the feedstock is available cheaply and in large quantities, and this requires major changes in the agricultural sector as stated already (e.g. see Hazell & Woods, 2007)[24].

Bioenergy offers many opportunities for revitalising rural areas by modernizing agriculture and generate local wealth often through new employment opportunities at far lower cost than in any other sector as shown above, although this may not be true in all cases. However, the current model offers little opportunities particularly to the poor to improve their livelihood (Oxfam International, 2007).

[24] The authors have reviewed a number of key issues and drivers that effect global agriculture; this paper gives a good overview of the agriculture.

10.1 First versus second generation of biofuels

First generation of biofuels is not obviously the best solution given the growing concern with the potential direct competition with food products such as a corn and cereals. Some of the criticisms are summarised below.

i) First generation- Major criticism- e.g. insufficient attention has been paid to:

- Direct competition with food crops will impact directly on food prices. In some cases, as in the US, expansion has been too rapid spearheaded by subsidies and short term investment interests, leaving little time to market forces to correct imbalances.
- There has been a failure to knowledge the wider potential impacts on agriculture and food security, and on the environment
- Failure to address the potential implications of biofuels in developing countries
- Uncertainties about the overall environmental benefits have not been properly assessed e.g. e of fertilizers, water, biodiversity, etc. This has allowed critics to question the overall benefits of biofuels; such critics argue that first generation of biofuels are not the solution for energy or the environment
- Weakness of certification/assurance criteria

For bioenergy to be produced efficiently and on a large scale, the problem of competition with food crops needs to be sorted out sort out first, and this can only be possible with fundamental changes in the agricultural system, as indicated above.

ii) Second generation

- Cellulose is the world's most abundant raw material and if ethanol can be produced in large scale this will go a long way to solve the feedstock problem. But, it is more highly dependent on the development of process technology which is still far from proven. In fact some critics argue that second generation of biofuels could be as damaging as the first (Smith, 2007), partly because currently there few (if any) commercial cellulose ethanol plant operating[25]. Currently four main processes are emerging: i) enzymatic hydrolysis, ii) acid hydrolysis, iii) thermo-chemical, and iv) gasification

- Competitive production of biofuels requires a modern agro-forestry production system and this needs financing capital, skills, know-how, etc. As a consequence, the tendency is toward land concentration, capital and so forth. Small farmers are unable to compete with large-scale production of biofuels and this poses some serious social and political problems.

Thus, despite the high expectations on the second generation of energy crops, and although this will represent a major step forward away from direct competition with

[25] There are various small-scale plants in operation, mostly in a semi-commercial scale

traditional food crops, there remain many unanswered questions. However, and although this technology will take time to develop, as with the oil industry which first developed kerosene, then gasoline, then unleaded gasoline and finally oxygenated gasoline, there is a potential for succeeding.

11 CONCLIONS

There are still many unanswered questions with regards to the overall socio-economic and environmental benefits of biofuels. Most of the criticism against ethanol fuel so far is not backed up by robust scientific facts. For example, *direct land competition* is a myth rather than a reality considering that merely about 1% of the global land area is currently dedicated to biofuels. Yet, they are widely blamed for current increase food prices. There are more than 2Gha of underexploited land, plus 700 Mha of other type of land that could be ed for non-food purposes. Producing between 5-20% of biofuels would not cause any problem if good management practices are put in place. If biofuels were to be introduced in very large scale, this could be far more problematic; a step-by-step strategy makes more sense[26]

It will be foolish to ignore the short- term impacts on food prices as a result the rapid expansion of biofuels, mainly in the US. Some increases, the combination of many factors, can have serious hurtful effects on the most vulnerable people. It is important, as the World Bank recognises (WB, 2008) to inform the general public of the pros and cons of biofuels through analysis, monitoring, and fair reporting of the facts. It also important to learn from past mistakes and lay a solid foundation for the development of biofuels

Food prices increases are very specific of certain locations and situations; on the whole biofuels are not the fundamental causes. Rather, price increases are the combination of many factors including unequal and unjust world food production and distribution systems, speculation and greed. Small farmers should be supported to produce food rather than let them to move to urban areas. For far too long agriculture has suffered from underinvestment and this situation needs to change.

[26] A step-by-step approach should be able to incorporate technical, economic, environmental and policy changes, that is, although growth will be slower, there will be less room for making more serious errors

Subsidies have been entrenched in the global energy system for many decades, of which fossil fuels have been, and remain so, the main beneficiaries. Biofuels receive a small proportion of subsidies by comparison.

The debate on *food versus fuel* must go beyond the narrow confines of vested interests, misinterpretations, and over simplistic arguments[27]. Still, it is recognised that this argument will not go away since there remain too many uncertainties which cannot be answered in the short-term. Bioenergy is very much influenced by local conditions and hence subject to large variations.

Will our concern with the environment, sustainability, and biodiversity leads to the imposition of requirements so stringent that it will hinder (or even prevent) rather than enhance the development of biofuels? Will there be a fair playing field for biofuels?

There is not any magic formula or perfect fuel, and thus it is important to devise strategies that allow for the best possible e of biomass resources on a fair playing field. Biofuels will not be the panacea for solving the transportation fuel problem, but can make a significant contribution to the fuel mix.

[27] Because there is not any certain evidence to support either view, it is very difficult to present a solid case either in favour or against on the food versus fuel issue.

11. MAIN REFERENCES

Berg, C. World Fuel Ethanol Analysis and Outlook; 2004 (http://www.distill.com/World-Fuel-Ethanol-A&O-2004.html)

Bergsma B, Kampman H, Croezen, Sevenster M (2007) Biofuels and their global influence on land availability for agriculture and nature: a first evaluation and a proposal for further fact finding. Delft, Netherlands, CE Delft. 07.8328.03:1-84.

Brown L (2007) Biofuels for Transport: Global Potential and Implications for Stainable Agriculture and Energy in the 21st Century, World Watch Institute, ISBN 978-1-84407-422-8 (www.worldwatch.org/)

Crutzen P J, Mosier A R, Smith K A, Winiwarter W., (2007) NO2 Release from Agro-fuels Production Negates Global Warming Reduction by Replacing Fossil Fuels, Atmos. Chem. Phys. Discs., 7 pp 11191-11205

Doornbosch R, Steenblik R., (2007) Biofuels: Is the cure worst than the disease? Round Table on Stainable Development, OECD General Secretariat (Draft report SG/SD/TR (2007)3, Paris

Dufey A (2006) Biofuels Production, Trade and Stainable Development: Emerging Issues, Intern. Inst. for Environment and Development (IIED), London, ISBN: 978-1-84369-643-8

EC (2007) Biofuels Progress Report, Review of Economic and Environmental Data for the Biofuels Progress Report, [COM(2006) 845 Final] [SEC(2007) 12]

FAO (2007) Stainable Bioenergy: A Framework for Decision Makers, UN-FAO

Fulton, L. (2004). Recent Biofuels Assessments and Two New Scenarios, IEA Paper presented at the IEA Seminar Assessing the Biofuels Option, Paris. June.

GAO (2000) Tax incentives for Petroleum and Ethanol Fuels: Descriptions, Legislative Histories, and Revenue Loss Estimates, GAO, [General Accounting Office of the US], Washington D.C

Hausmann R (2007) Biofuels- Can Match Oil Production, Centre for International Development, Harvard University. See also The Financial Times on 07/11/2007 (www.ft.com/cms/s/0330

Hazel P & Woods S. (2007) Drivers of Change on Global Agriculture, Philosophical Transactions of the Royal Society B. (2008): 363: 495-515

Junginger M, Faaij A, Rosillo-Calle F, Woods J. (2006) A Growing Role of Bioenergy- Opportunities, Challenges and Pitfalls of the Biofuel Trade, Renewable Energy World Vol. 9 (5): 130 – 141. Reprinted in Int. Sugar Journal, Vol. 108 (1295): 618-629

Koplow D., (2007) Biofuels: At what costs? Government Support for Ethanol and Biodiesel in the United States: 2007 Update, Global Subsidies Institute (GSI). International Inst. for Stainable Development (IISD), Geneva, October 2007 (www.iisd.org; www.globalsubsidies.org)

Kutas G, Lindberg C, Steenblik R., Koplow D. (2007) Biofuels: At What Costs? Governments support for ethanol and biodiesel in the European Union. Global Subsidies Institute (GSI). International Inst. for Stainable Development (IISD), Geneva, October 2007 (www.iisd.org; www.globalsubsidies.org)

Macedo I C, Leal, MRLV, Silva, JEAR (2004) Assessment of Greenhouse Gases Emissions in the Production and Use of Fuel Ethanol in Brazil. Secretariat of the Environment – State of São Paulo

Moreira, J. R. (2006) Global Biomass Energy Potential. *Mitigation and Adaptation Strategies for Global Change* DOI: 10.1007/s11027-005-9009-2:313-342.

Mazoyer M, Roudart L (2006) A History of World Agriculture- From the Neolithic Age to Current Crisis, Earthcan, London, ISBN 1-84407-399-8

Oxfam Intern (2007) Bio-fuelling Poverty: Why the EU Renewable-fuel Target May be Disastro for Poor People, Oxfam International, Oxford, UK.

Rao K K & Hall D O, (1999) Photosynthesis, 6th Edition, Studies in Biology, Cambridge University Press.

Rosillo-Calle & Hall (1987) Brazilian Alcohol- Food versus Fuel, Biomass 12 (2): 97-128.

Rosillo-Calle, F., (2006) Biomass Energy- On Overview, in: Landolf-Bornstein Handbook, Vol. 3 (C): Energy Technologies, Springer, Chapter 5 pp. 334- 373; ISBN 3-540-429662-X.

ROYAL SOCIETY (2008) Stainable Biofuels: Prospects and Challenges, Royal Society, London, ISBN 978 0 85403 662 2

Searchinger T, Heimlich R, Houghton R A, Dong F, Elobied A, Fabiosa J, Tokgoz S, Hayes D, Yu T-H., (2008) e of Cropland Increases GHG through Emissions from Land e Change, www.scienceexpress.org, 7 Feb/08, p.1/10.1126

Shapouri, H, Duffield, JA, Graboski, MS (1995) Estimating the net energy balance of corn ethanol, Department of Agriculture, Agricultural Economic Report Number 721; 1995

Shapouri, H, Duffield, JA, Wang M., (2002) The Energy Balance of Corn Ethanol: An Update, DA, Office of Energy Policy and New es, Agriculture Economic Report No. 813

Sheehan J, Camobreco V, Duffield J, Graboski M, Shapouri H., (1998) An Overview of Biodiesel and Petroleum Diesel Life Cycles, NREL, Golden, CO, Reporrt NREL/TP-500-24772

Smith F B, (2007) Corn-based Ethanol: A Case Study in the Law of Unintended Consequences, Competitive Enterprises Institute, Issue Analysis 6 (June). (www.cei.org/pdf5976.pdf)

UNCTAD (2006).The Emerging Biofuels Market: Regulatory, and Development Implications, New York/Geneva.

Walter A, Rosillo-Calle, F, Dolzan P, Piacente E, Borges da Cunha K., (2008). Perspectives on fuel ethanol consumption and trade, Biomass and Bioenergy (in press)

Wang, M, Wu, M, Huo, H (2007) Life-cycle energy and greenhoe gas emission impacts of different corn ethanol plant types. Environmental Research Letters 2007; 2, 13

WOLD BANK (2008) Rising Food Prices: Policy Options and World Bank Response, Background Note for the Development Committee, Washington, DC,

Woods, J. (2007) Stainable Biofuel Systems: opportunities and threats. Royal Society: International Biofuel Opportunities Workshop. London, 23rd to 24th April, 2007

WI (World Watch Institute) (2007) Biofuels for Transport- Global potential and implications for stainable energy and agriculture, Earthscan, London, ISBN-13: 978-1-84407

Wu, M, Wang, M, Huo, H. (2006) Fuel-Cycle Assessment of Selected Bioethanol Production Pathways in the United States. Argonne National Laboratory, Report ANL/ESD/06-7, Chicago

Zah R, Boni H, Gauch M, Hischier R, Lehmann M, Wager P., (2007) Life Cycle Assessment of Energy Products- Environmental Impacts Assessment of Biofuels, EMPA Technology and Society Lab (www.empa.ch/tsl)